US007593980B2

(12) **United States Patent**
Marascio et al.

(10) **Patent No.: US 7,593,980 B2**
(45) **Date of Patent: Sep. 22, 2009**

(54) **APPLICATION SERVER SYSTEM AND METHOD**

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(73) Assignee: **Cisco Technology, Inc.**, San Jose, CA (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 582 days.

(21) Appl. No.: **10/999,888**

(22) Filed: **Nov. 30, 2004**

(65) **Prior Publication Data**

US 2006/0136914 A1 Jun. 22, 2006

(51) **Int. Cl.**
G06F 15/16 (2006.01)

(52) **U.S. Cl.** **709/201**; 717/107; 717/118; 379/229

(58) **Field of Classification Search** 709/201, 709/207, 223; 379/220.01, 211.01, 229; 717/124, 109, 11; 715/967; 395/712
See application file for complete search history.

(56) **References Cited**

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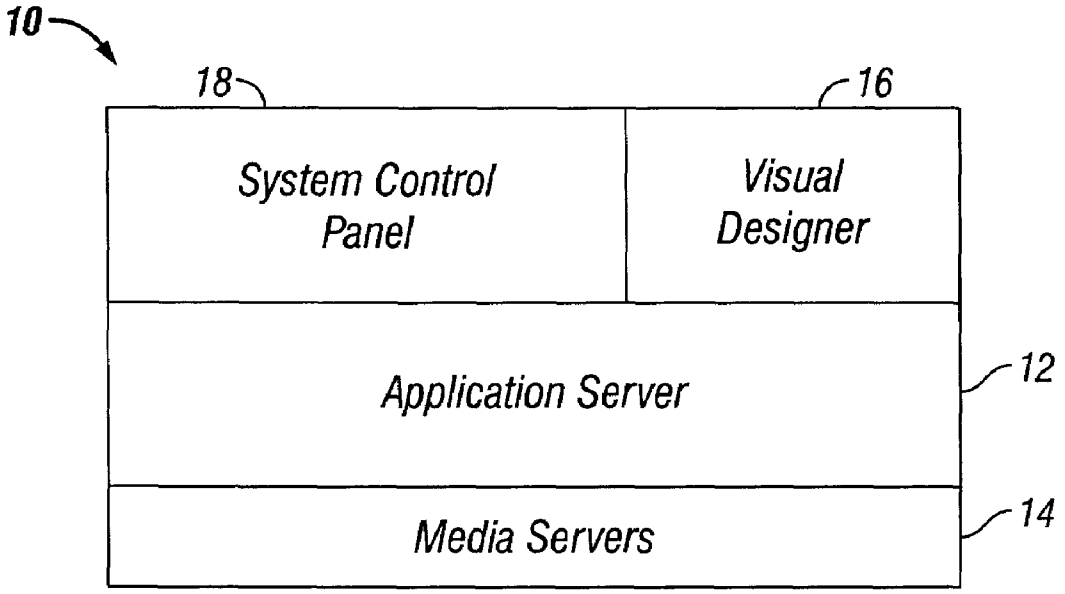
Assistant Examiner—Maria El-Zoobi
(74) *Attorney, Agent, or Firm*—Trellis IP Law Group, PC

(57) **ABSTRACT**

An application server system is provided having a core engine connecting one or more protocol providers to one or more applications. In a preferred embodiment, the one or more applications run on a respective one or more virtual machines having their own execution threads. A thread pool may be used to spawn instances of applications or scripts. Preferably, the core engine, the protocol providers, and each of the one or more virtual machines run in separate AppDomains. In another embodiment, a visual designer is provided preferably having XML conversion capability and interactive debug capability.

20 Claims, 25 Drawing Sheets



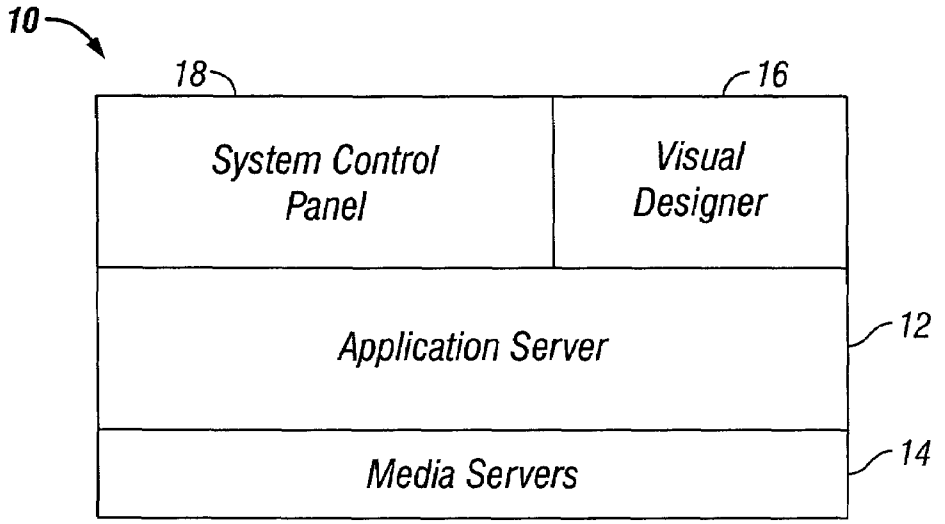

10
18
16
System Control Panel
Visual Designer
Application Server
12
Media Servers
14

FIG. 1

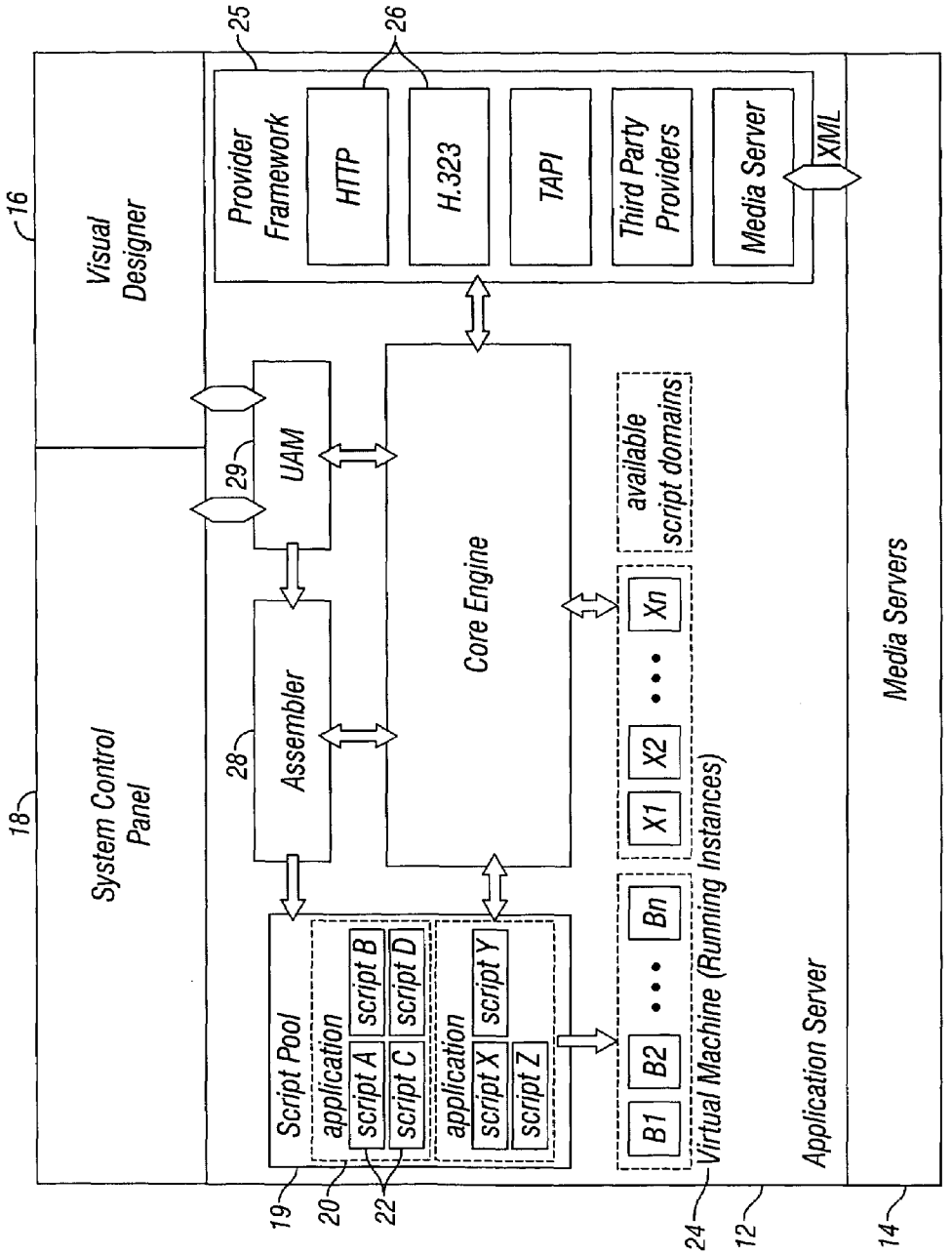

16
Visual Designer
18
System Control Panel
25
26
Provider Framework
HTTP
H.323
TAPI
Third Party Providers
Media Server
XML
29
UAM
28
Assembler
Core Engine
available script domains
Xn
X2
X1
Bn
B2
B1
Virtual Machine (Running Instances)
Media Servers
Application Server
Script Pool
application
script A
script B
script C
script D
application
script X
script Y
script Z
19
20
22
24
12
14

FIG. 2

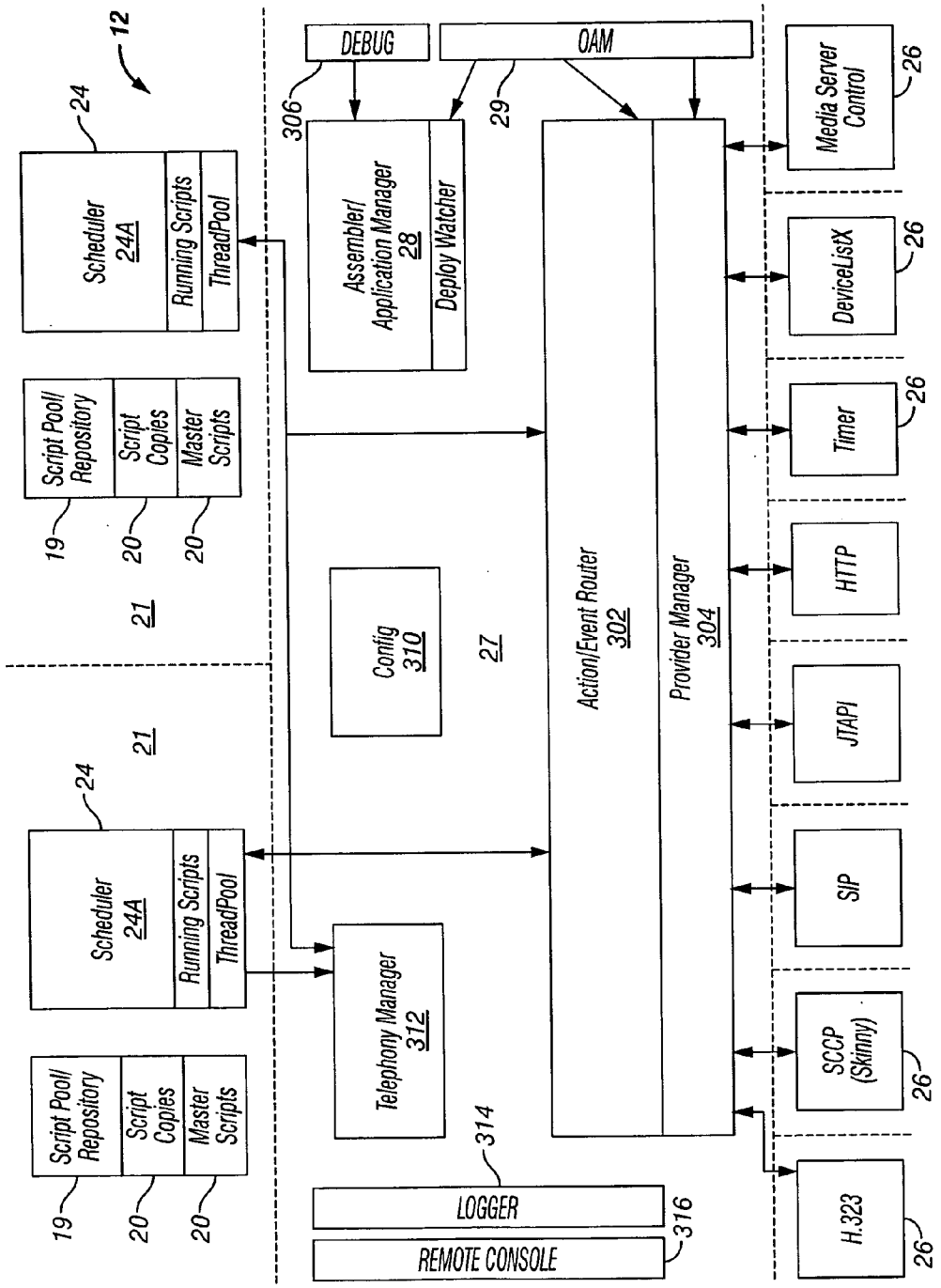

12
24
Scheduler 24A
Running Scripts
ThreadPool
Script Pool/ Repository
Script Copies
Master Scripts
19
20
20
21
21
24
Scheduler 24A
Running Scripts
ThreadPool
Script Pool/ Repository
Script Copies
Master Scripts
19
20
20
DEBUG
306
OAM
29
Assembler/ Application Manager 28
Deploy Watcher
Config 310
27
Telephony Manager 312
314
LOGGER
REMOTE CONSOLE
316
Action/Event Router 302
Provider Manager 304
Media Server Control
26
DeviceListX
26
Timer
26
HTTP
JTAPI
SIP
SCCP (Skinny)
26
H.323
26

FIG. 3

	Incoming Event	App1	App2	App3
Event Name	MyEvent	MyEvent	MyEvent	MyEvent
Parameter1	42		42	42
Parameter2	Red			green

FIG. 4A

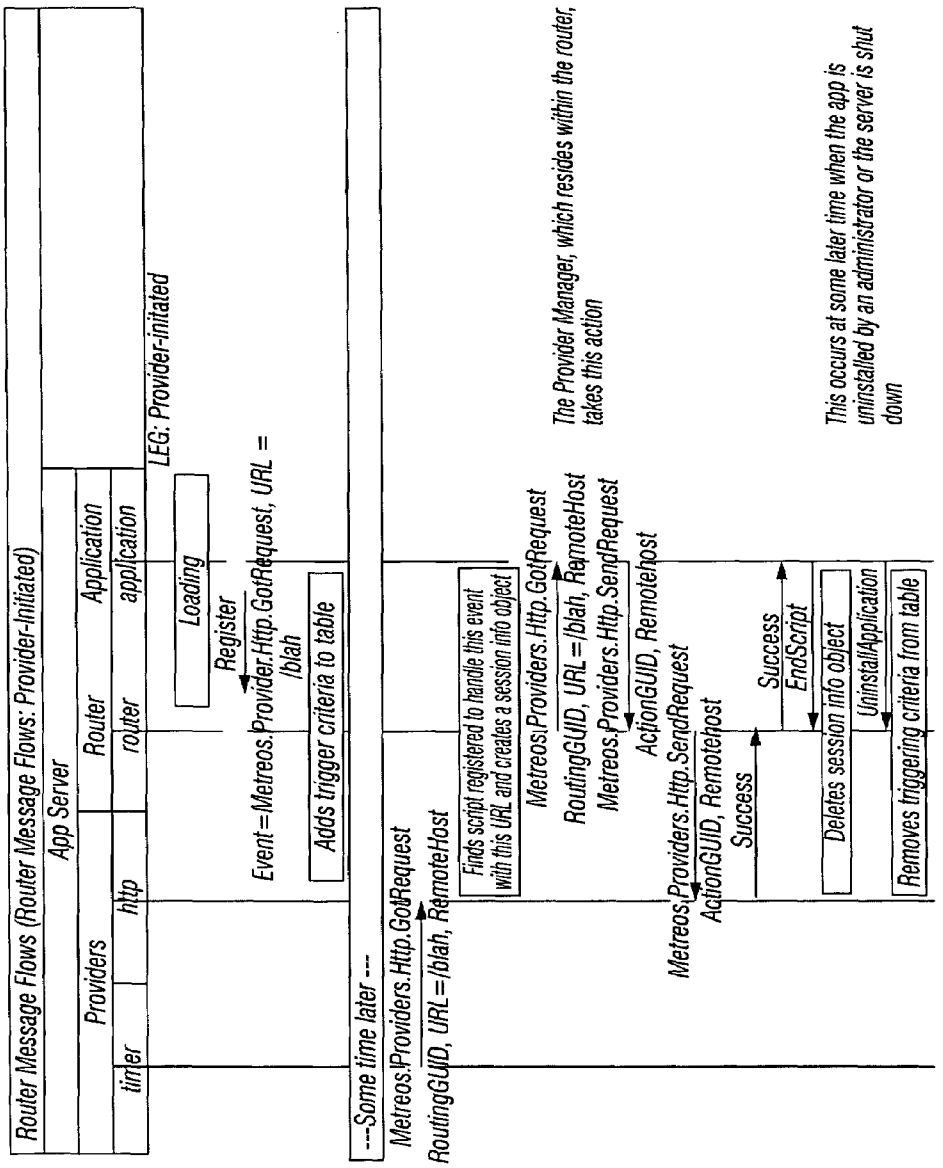

Router Message Flows (Router Message Flows: Provider-Initiated)
App Server
Providers
Router
Application
timer
http
router
application
LEG: Provider-initiated
Loading
Register
Event=Metreos.Provider.Http.GotRequest, URL = /blah
Adds trigger criteria to table
---Some time later ---
Metreos.Providers.Http.GotRequest
RoutingGUID, URL=/blah, RemoteHost
Finds script registered to handle this event with this URL and creates a session info object
Metreos.Providers.Http.GotRequest
RoutingGUID, URL=/blah, RemoteHost
The Provider Manager, which resides within the router, takes this action
Metreos.Providers.Http.SendRequest
ActionGUID, RemoteHost
Metreos.Providers.Http.SendRequest
ActionGUID, RemoteHost
Success
Success
EndScript
Deletes session info object
This occurs at some later time when the app is uninstalled by an administrator or the server is shut down
UninstallApplication
Removes triggering criteria from table

FIG. 4B

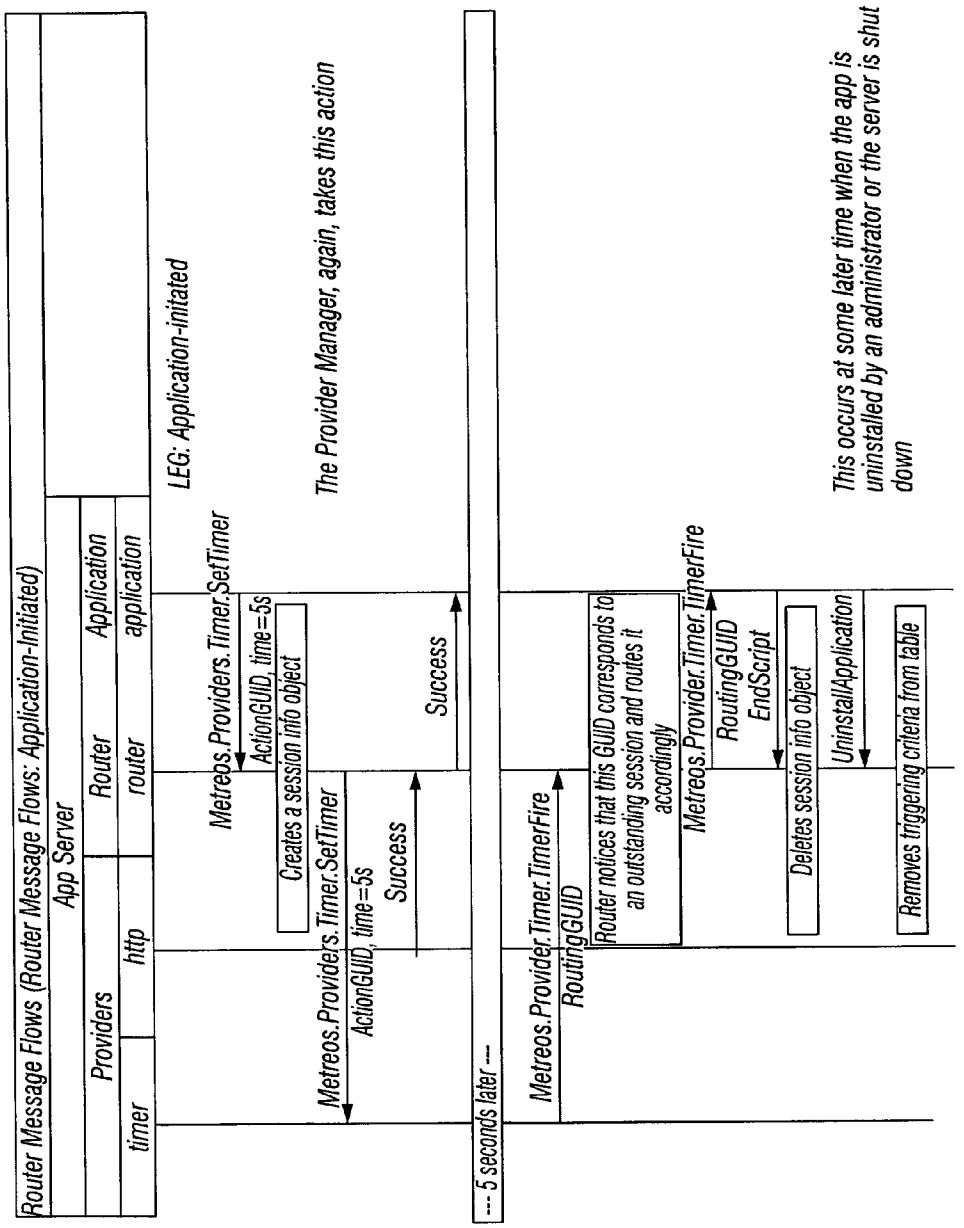

Router Message Flows (Router Message Flows: Application-Initiated)
App Server
timer
Providers
http
Router
router
Application
application
LEG: Application-initated
Metreos.Providers.Timer.SetTimer
ActionGUID, time=5s
Creates a session info object
Success
The Provider Manager, again, takes this action
Metreos.Providers.Timer.SetTimer
ActionGUID, time=5s
Success
--- 5 seconds later ---
Metreos.Provider.Timer.TimerFire
RoutingGUID
Router notices that this GUID corresponds to an outstanding session and routes it accordingly
Metreos.Provider.Timer.TimerFire
RoutingGUID
EndScript
Deletes session info object
UninstallApplication
Removes triggering criteria from table
This occurs at some later time when the app is uninstalled by an administrator or the server is shut down

FIG. 4C

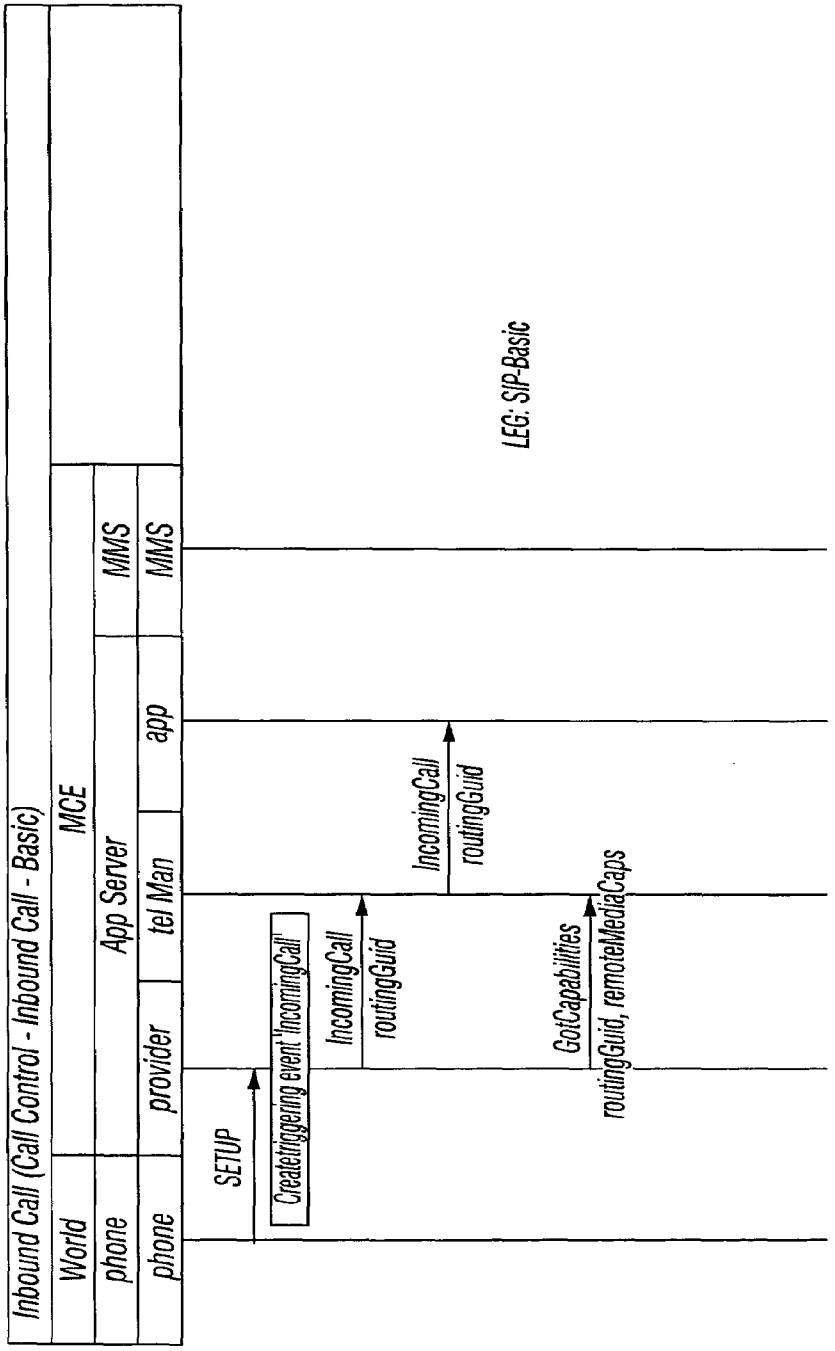

Inbound Call (Call Control - Inbound Call - Basic)
World
phone
phone
MCE
App Server
MMS
provider
tel Man
app
MMS
SETUP
Createtriggering event 'IncomingCall'
IncomingCall
routingGuid
IncomingCall
routingGuid
GotCapabilities
routingGuid, remoteMediaCaps
LEG: SIP-Basic

FIG. 4D

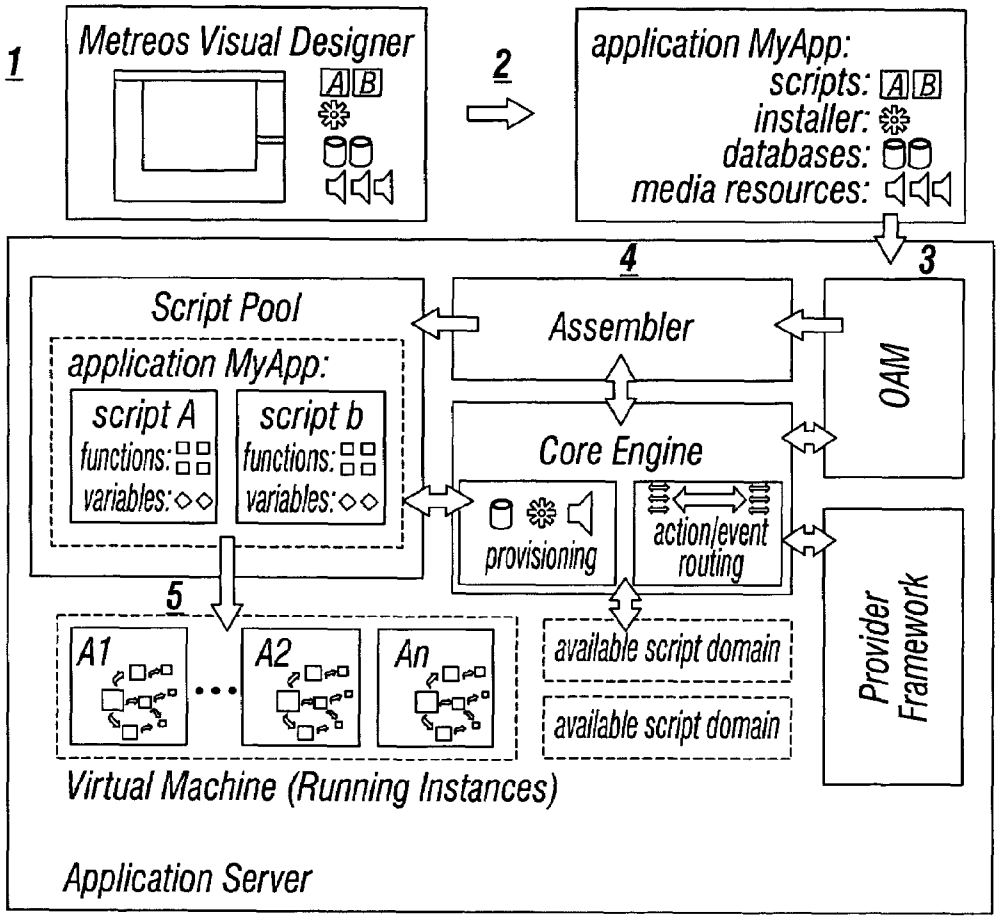

1
Metreos Visual Designer
A B
2
application MyApp:
scripts: A B
installer:
databases:
media resources:
4
3
Script Pool
application MyApp:
script A
functions:
variables:
script b
functions:
variables:
Assembler
OAM
Core Engine
provisioning
action/event routing
5
A1
A2
An
available script domain
available script domain
Provider Framework
Virtual Machine (Running Instances)
Application Server

FIG. 5

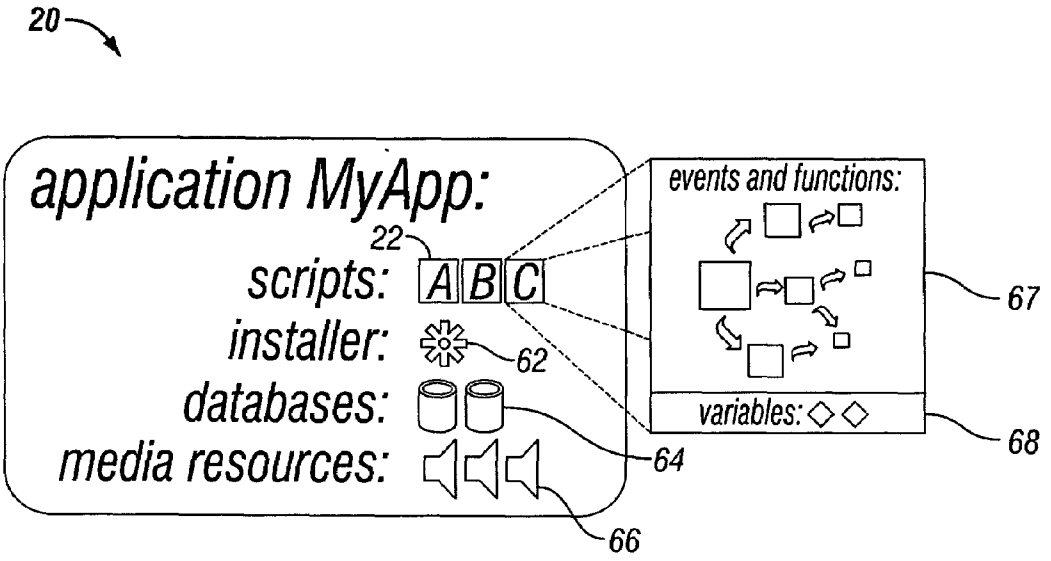

20
application MyApp:
22
scripts: A B C
installer:
62
databases:
media resources:
64
66
events and functions:
67
variables:
68

FIG. 6

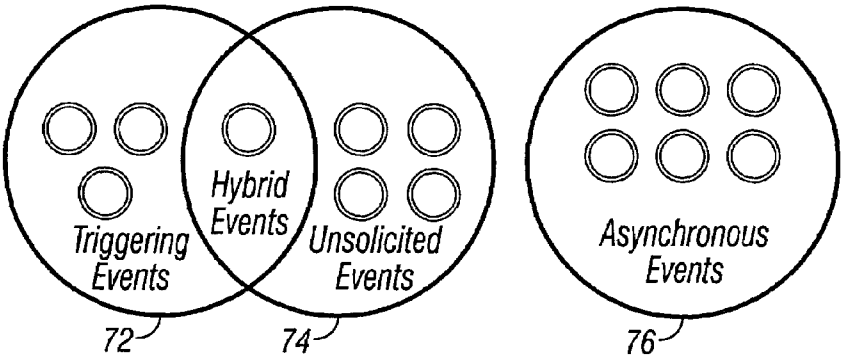

Triggering Events
Hybrid Events
Unsolicited Events
Asynchronous Events
72
74
76

FIG. 7

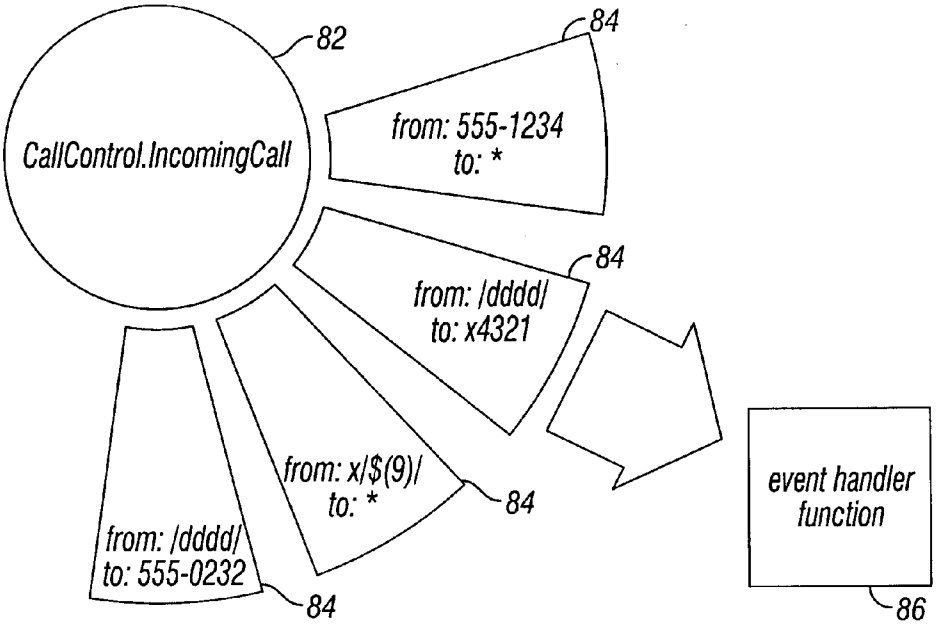

82
CallControl.IncomingCall
84
from: 555-1234
to: *
84
from: /dddd/
to: x4321
from: x/$(9)/
to: *
84
from: /dddd/
to: 555-0232
84
event handler
function
86

FIG. 8

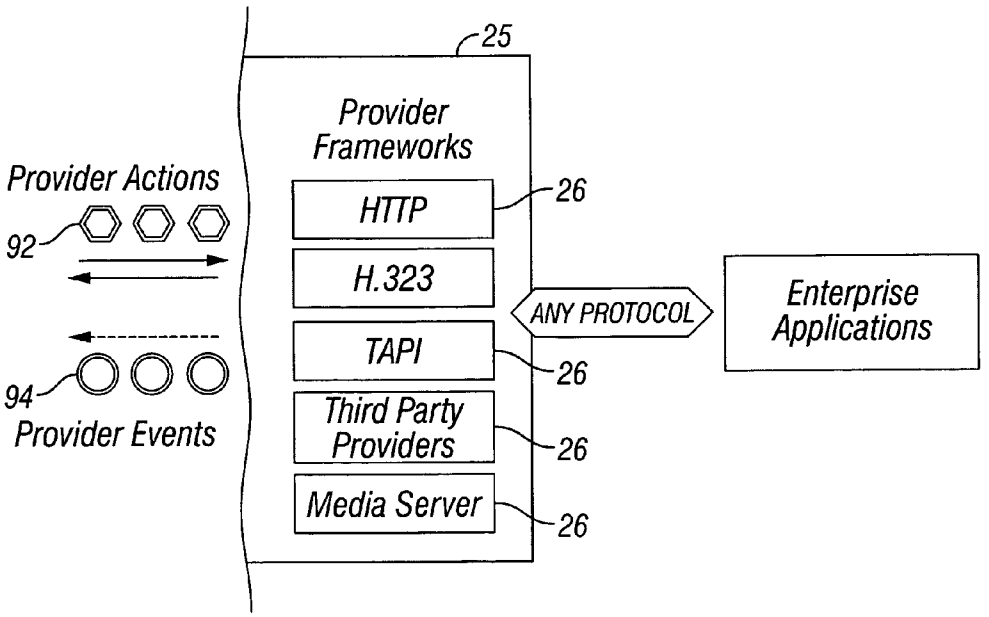

25
Provider
Frameworks
Provider Actions
92
HTTP
26
H.323
ANY PROTOCOL
Enterprise
Applications
TAPI
26
94
Provider Events
Third Party
Providers
26
Media Server
26

FIG. 9

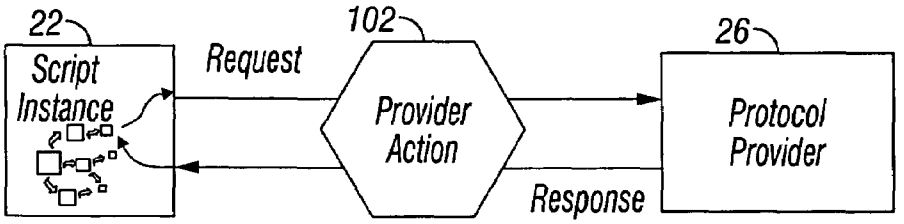

22
Script
Instance
Request
102
Provider
Action
26
Protocol
Provider
Response

FIG. 10

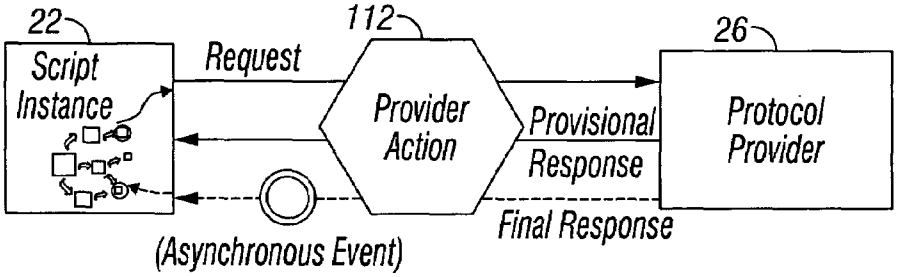

22
Script
Instance
Request
112
Provider
Action
26
Protocol
Provider
Provisional
Response
Final Response
(Asynchronous Event)

FIG. 11

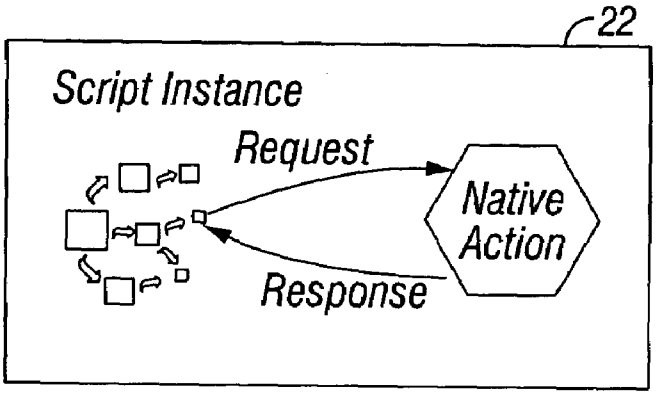

22
Script Instance
Request
Native Action
Response

FIG. 12

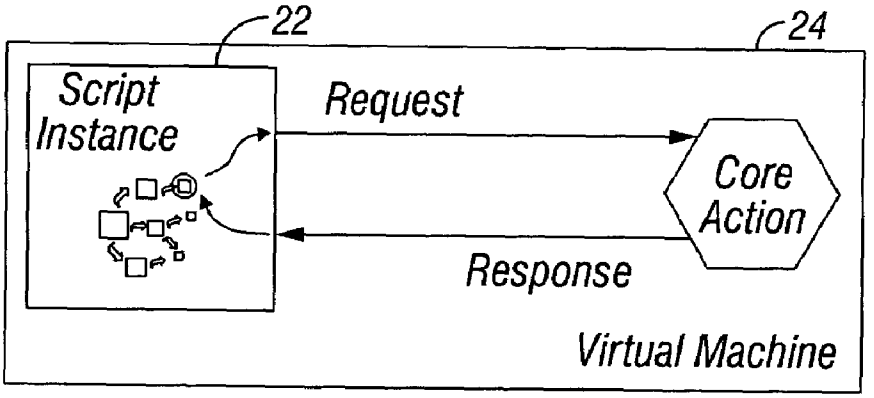

22
24
Script Instance
Request
Core Action
Response
Virtual Machine

FIG. 13

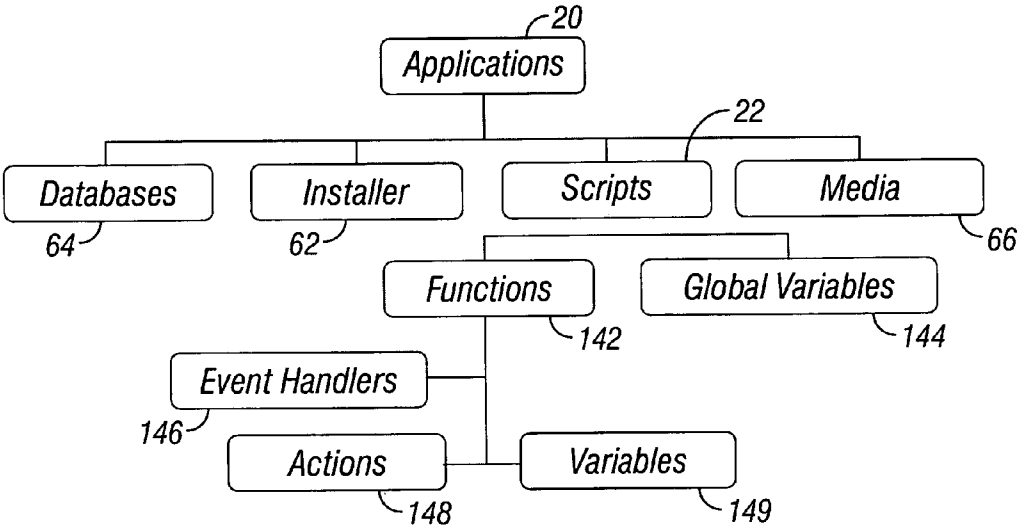

20
Applications
22
Databases
Installer
Scripts
Media
64
62
66
Functions
Global Variables
142
144
Event Handlers
146
Actions
Variables
148
149

FIG. 14

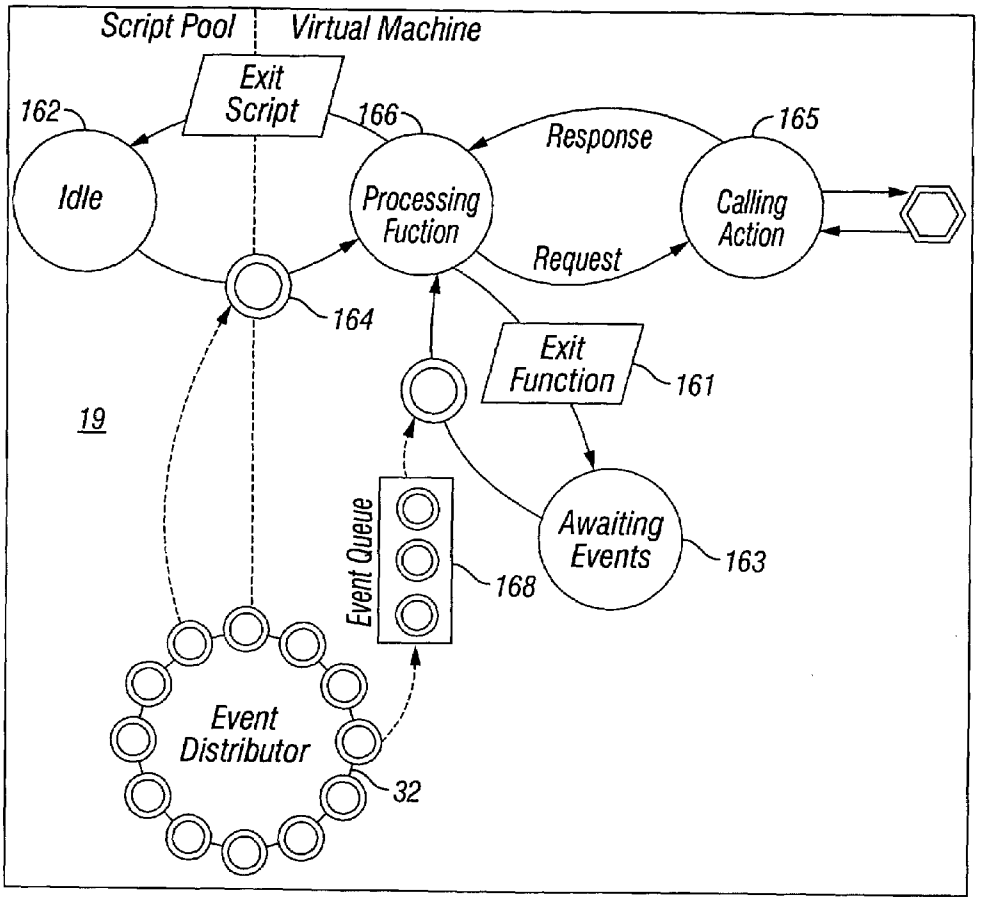

Script Pool
Virtual Machine
Exit Script
162
166
165
Response
Idle
Processing Fuction
Calling Action
Request
164
Exit Function
161
19
Awaiting Events
163
Event Queue
168
Event Distributor
32

FIG. 15

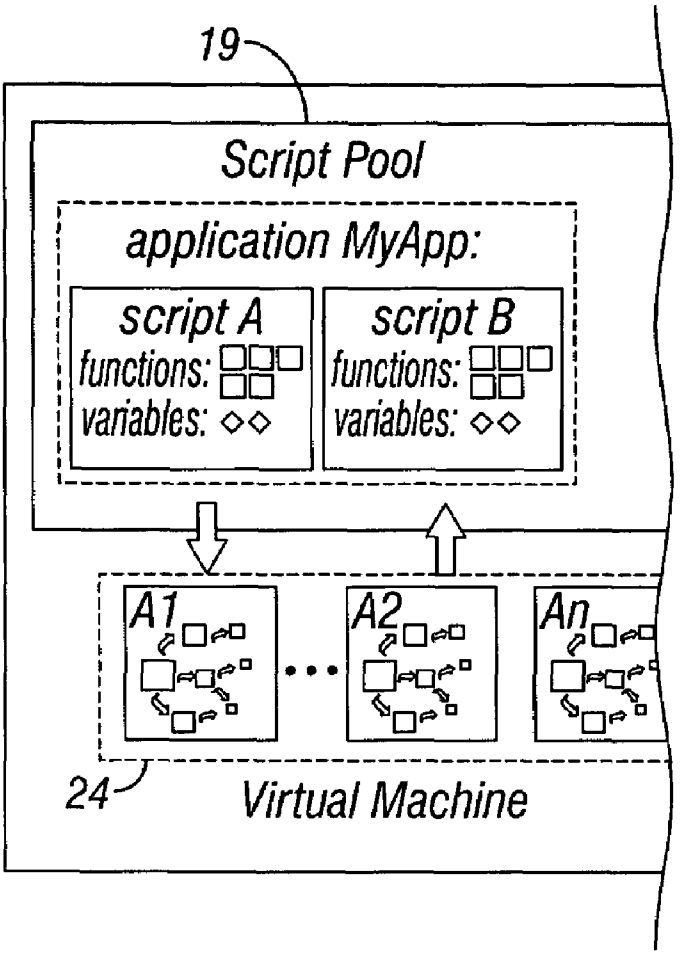

19
Script Pool
application MyApp:
script A
functions:
variables:
script B
functions:
variables:
A1
A2
An
24
Virtual Machine

FIG. 16

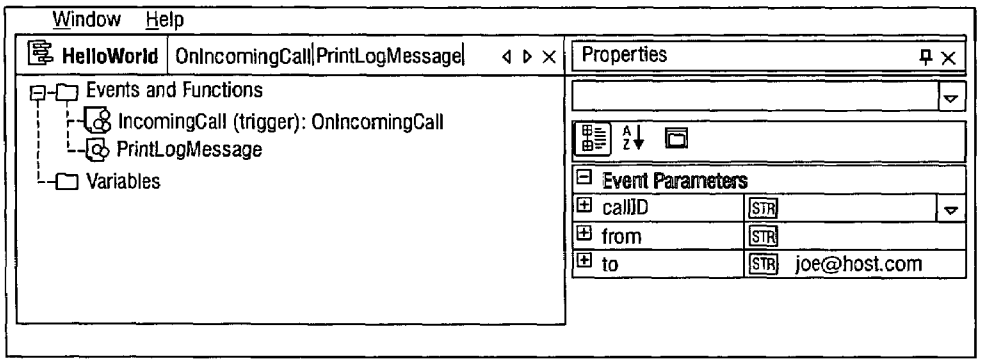

Window Help
HelloWorld
OnIncomingCall
PrintLogMessage
Properties
Events and Functions
IncomingCall (trigger): OnIncomingCall
PrintLogMessage
Variables
Event Parameters
callID
from
to
joe@host.com

FIG. 17

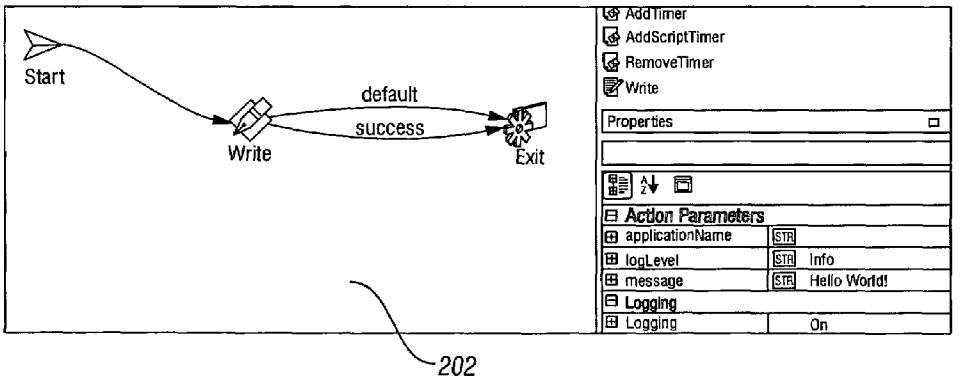

Start
default
success
Write
Exit
AddTimer
AddScriptTimer
RemoveTimer
Write
Properties
Action Parameters
applicationName
logLevel
Info
message
Hello World!
Logging
Logging
On
202

FIG. 18

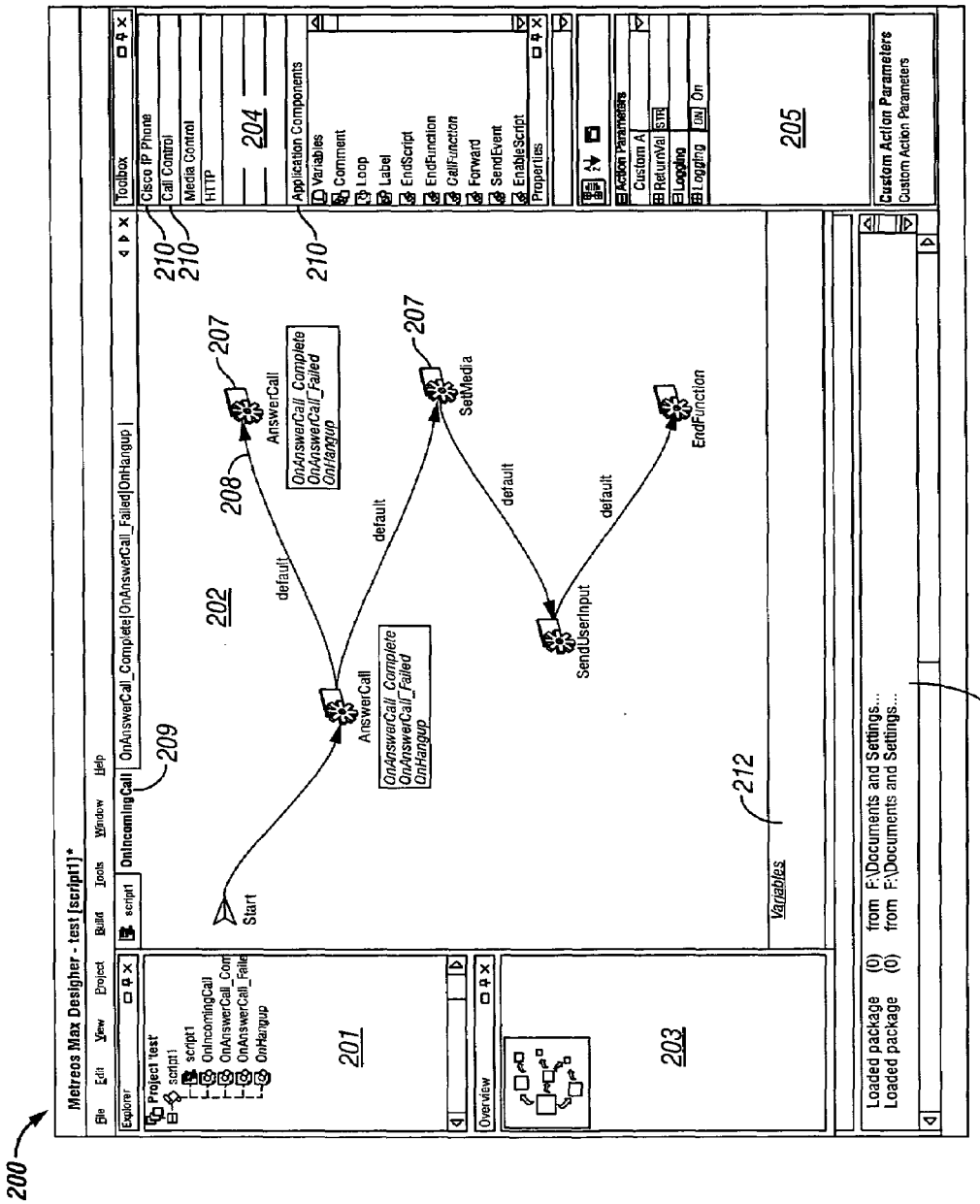

Metreos Max Designer - test [script1]*
File Edit View Project Build Tools Window Help
Explorer
Project 'test'
script1
OnIncomingCall
OnAnswerCall_Com
OnAnswerCall_Faile
OnHangup
201
Overview
203
script1
OnIncomingCall
OnAnswerCall_Complete|OnAnswerCall_Failed|OnHangup
209
202
Start
AnswerCall
OnAnswerCall_Complete
OnAnswerCall_Failed
OnHangup
208
207
default
SetMedia
SendUserInput
EndFunction
Variables
212
Toolbox
Cisco IP Phone
Call Control
Media Control
HTTP
204
Application Components
Variables
Comment
Loop
Label
EndScript
EndFunction
CallFunction
Forward
SendEvent
EnableScript
Properties
210
Action Parameters
Custom A
ReturnVal
Logging
On
205
Custom Action Parameters
Custom Action Parameters
Loaded package (0) from F:\Documents and Settings...
Loaded package (0) from F:\Documents and Settings...
206
200

FIG. 19

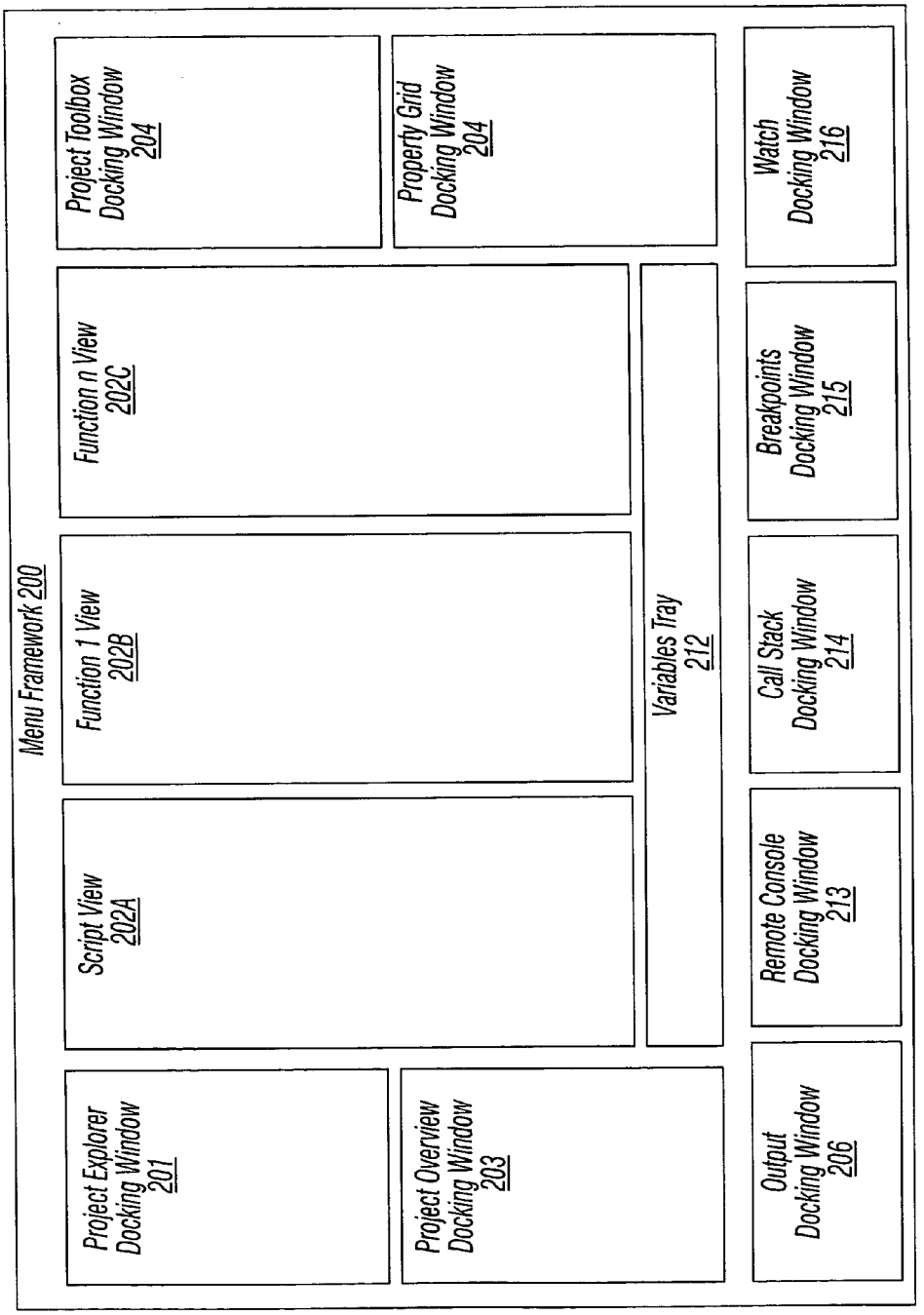

Menu Framework 200
Project Explorer Docking Window 201
Script View 202A
Function 1 View 202B
Function n View 202C
Project Toolbox Docking Window 204
Project Overview Docking Window 203
Variables Tray 212
Property Grid Docking Window 204
Output Docking Window 206
Remote Console Docking Window 213
Call Stack Docking Window 214
Breakpoints Docking Window 215
Watch Docking Window 216

FIG. 20

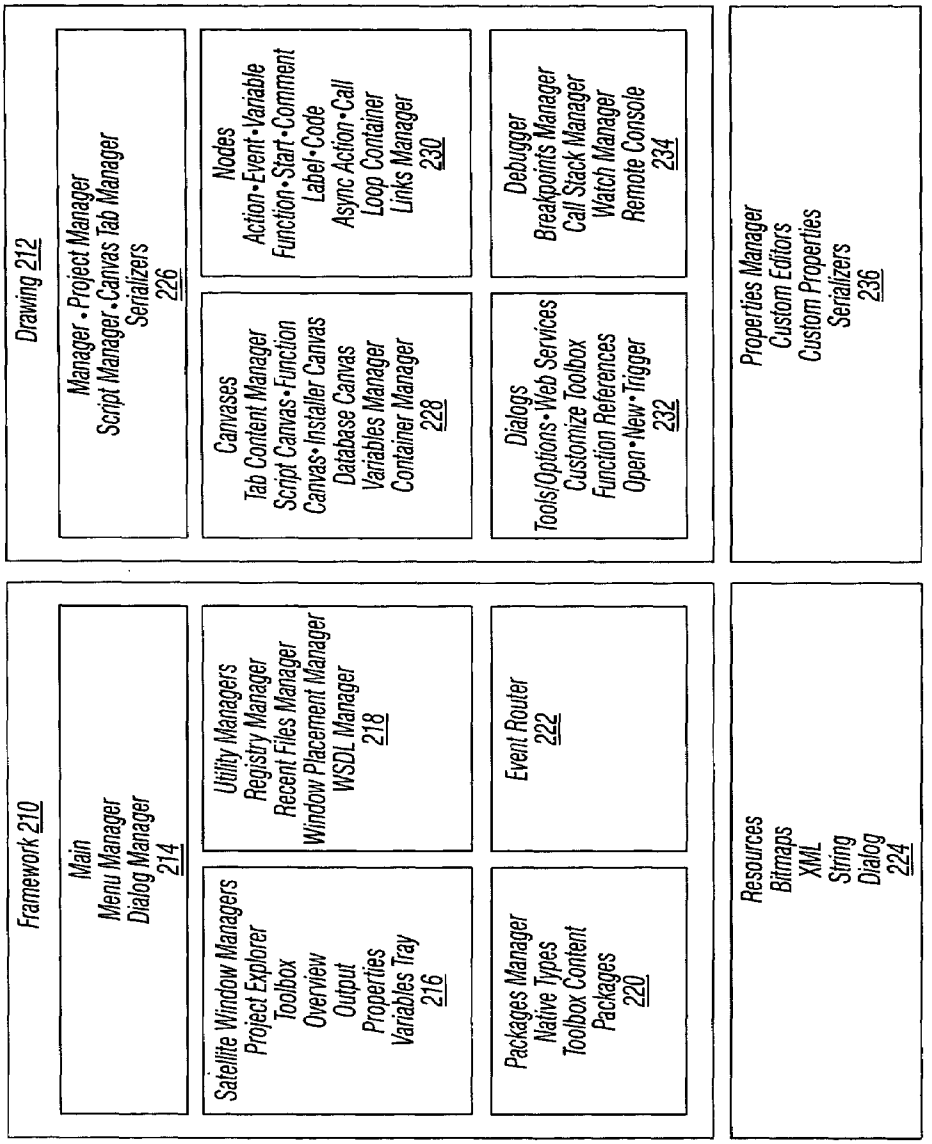

Framework 210
Main
Menu Manager
Dialog Manager
214
Satellite Window Managers
Project Explorer
Toolbox
Overview
Output
Properties
Variables Tray
216
Utility Managers
Registry Manager
Recent Files Manager
Window Placement Manager
WSDL Manager
218
Packages Manager
Native Types
Toolbox Content
Packages
220
Event Router
222
Resources
Bitmaps
XML
String
Dialog
224
Drawing 212
Manager • Project Manager
Script Manager • Canvas Tab Manager
Serializers
226
Canvases
Tab Content Manager
Script Canvas • Function
Canvas • Installer Canvas
Database Canvas
Variables Manager
Container Manager
228
Nodes
Action • Event • Variable
Function • Start • Comment
Label • Code
Async Action • Call
Loop Container
Links Manager
230
Dialogs
Tools/Options • Web Services
Customize Toolbox
Function References
Open • New • Trigger
232
Debugger
Breakpoints Manager
Call Stack Manager
Watch Manager
Remote Console
234
Properties Manager
Custom Editors
Custom Properties
Serializers
236

FIG. 21

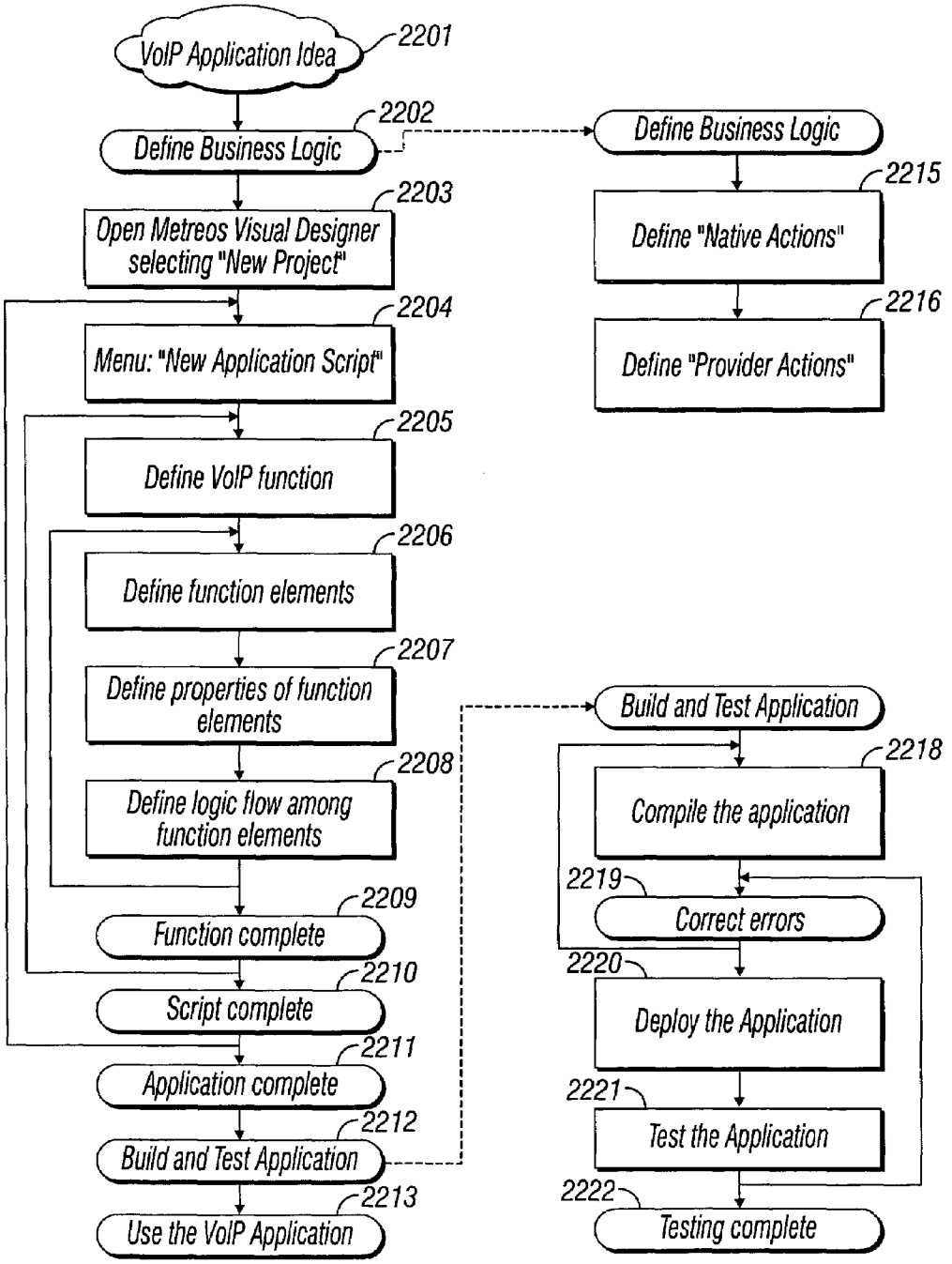

VoIP Application Idea
2201
Define Business Logic
2202
Open Metreos Visual Designer selecting "New Project"
2203
Menu: "New Application Script"
2204
Define VoIP function
2205
Define function elements
2206
Define properties of function elements
2207
Define logic flow among function elements
2208
Function complete
2209
Script complete
2210
Application complete
2211
Build and Test Application
2212
Use the VoIP Application
2213
Define Business Logic
Define "Native Actions"
2215
Define "Provider Actions"
2216
Build and Test Application
Compile the application
2218
Correct errors
2219
Deploy the Application
2220
Test the Application
2221
Testing complete
2222

FIG. 22

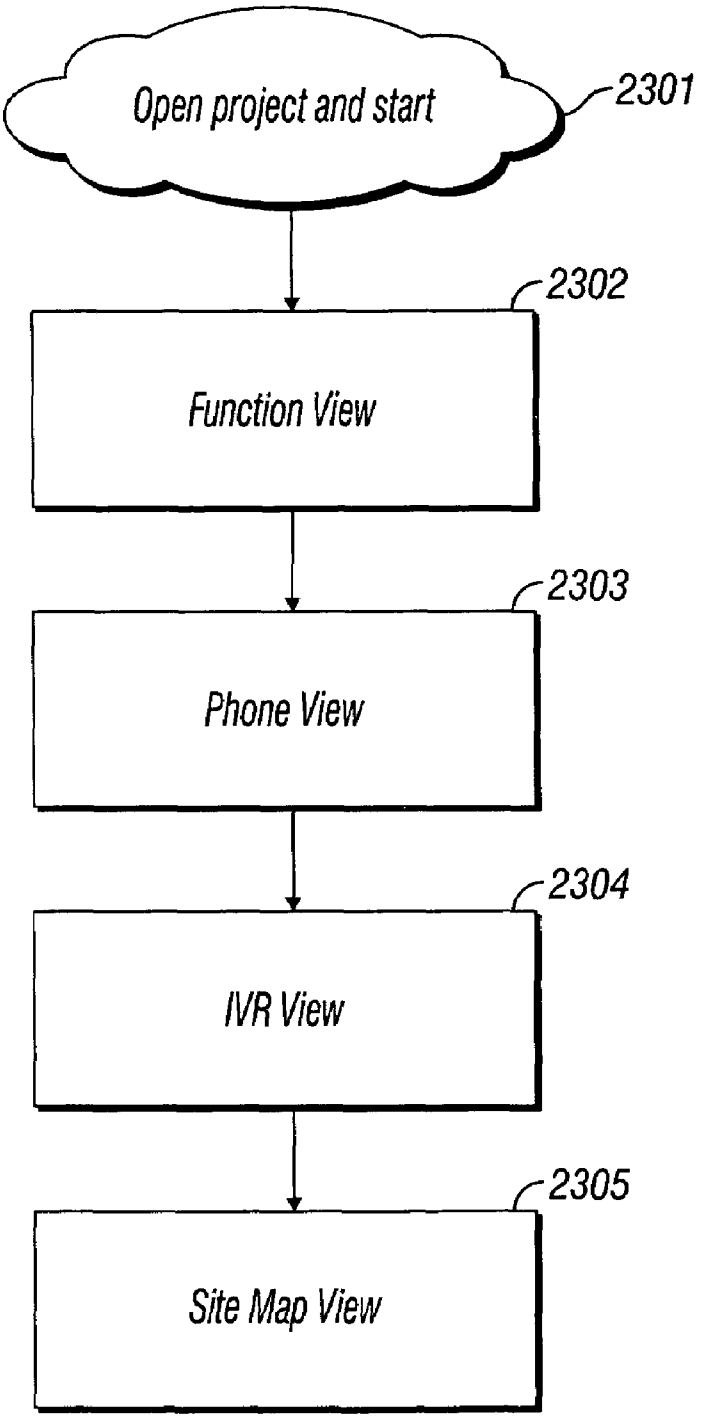

Open project and start
2301
2302
Function View
2303
Phone View
2304
IVR View
2305
Site Map View

FIG. 23

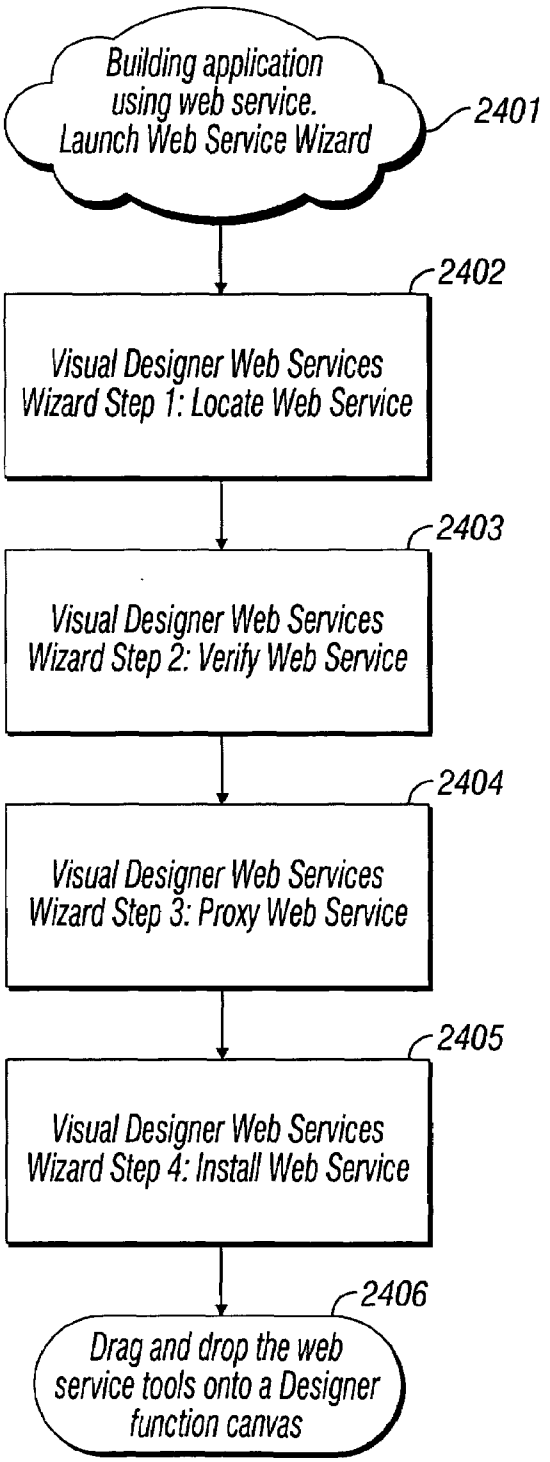

Building application using web service. Launch Web Service Wizard
2401
2402
Visual Designer Web Services Wizard Step 1: Locate Web Service
2403
Visual Designer Web Services Wizard Step 2: Verify Web Service
2404
Visual Designer Web Services Wizard Step 3: Proxy Web Service
2405
Visual Designer Web Services Wizard Step 4: Install Web Service
2406
Drag and drop the web service tools onto a Designer function canvas

FIG. 24

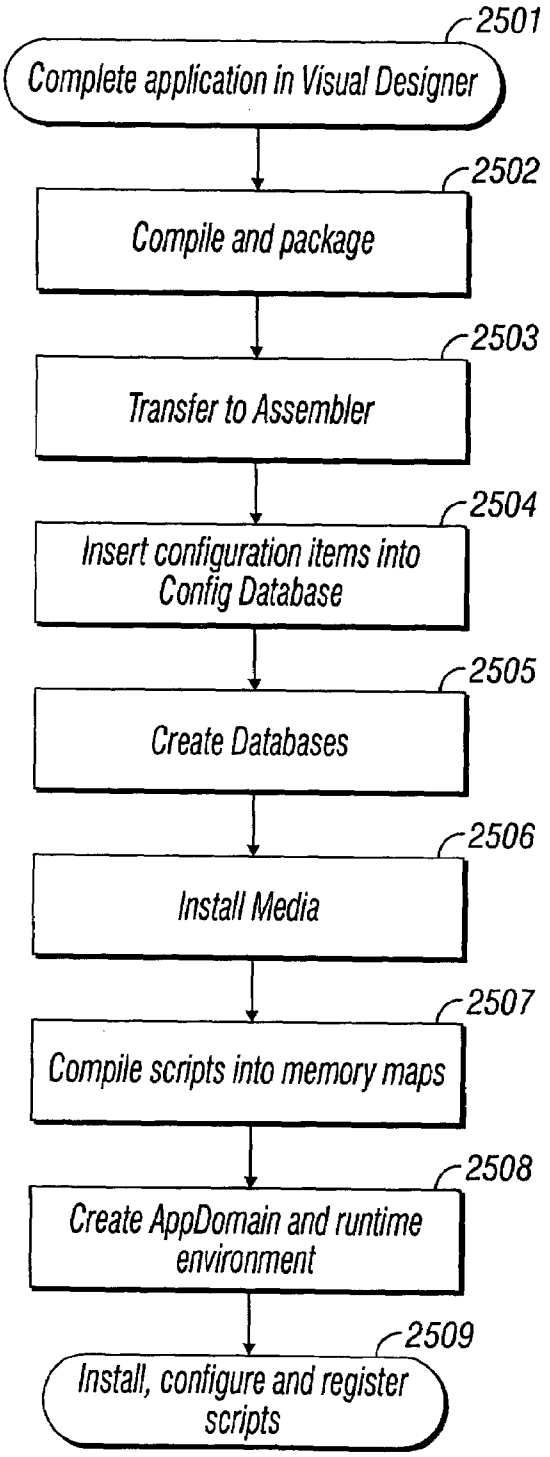

2501
Complete application in Visual Designer
2502
Compile and package
2503
Transfer to Assembler
2504
Insert configuration items into Config Database
2505
Create Databases
2506
Install Media
2507
Compile scripts into memory maps
2508
Create AppDomain and runtime environment
2509
Install, configure and register scripts

FIG. 25

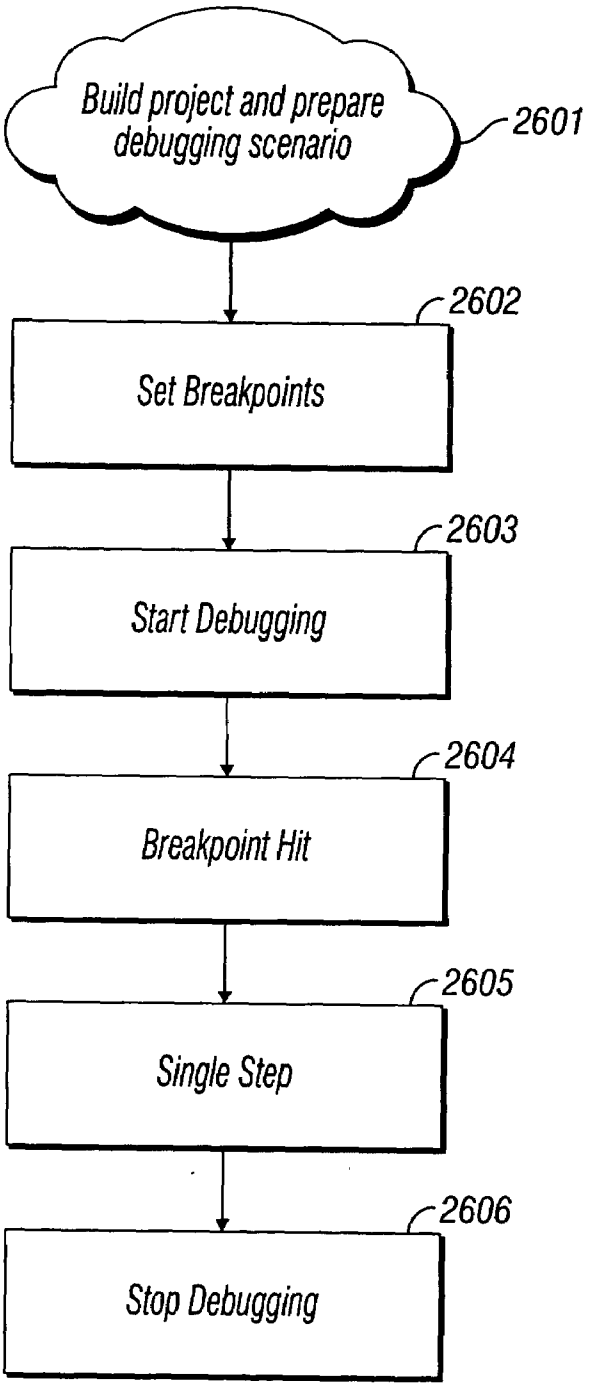

Build project and prepare debugging scenario
2601
2602
Set Breakpoints
2603
Start Debugging
2604
Breakpoint Hit
2605
Single Step
2606
Stop Debugging

FIG. 26

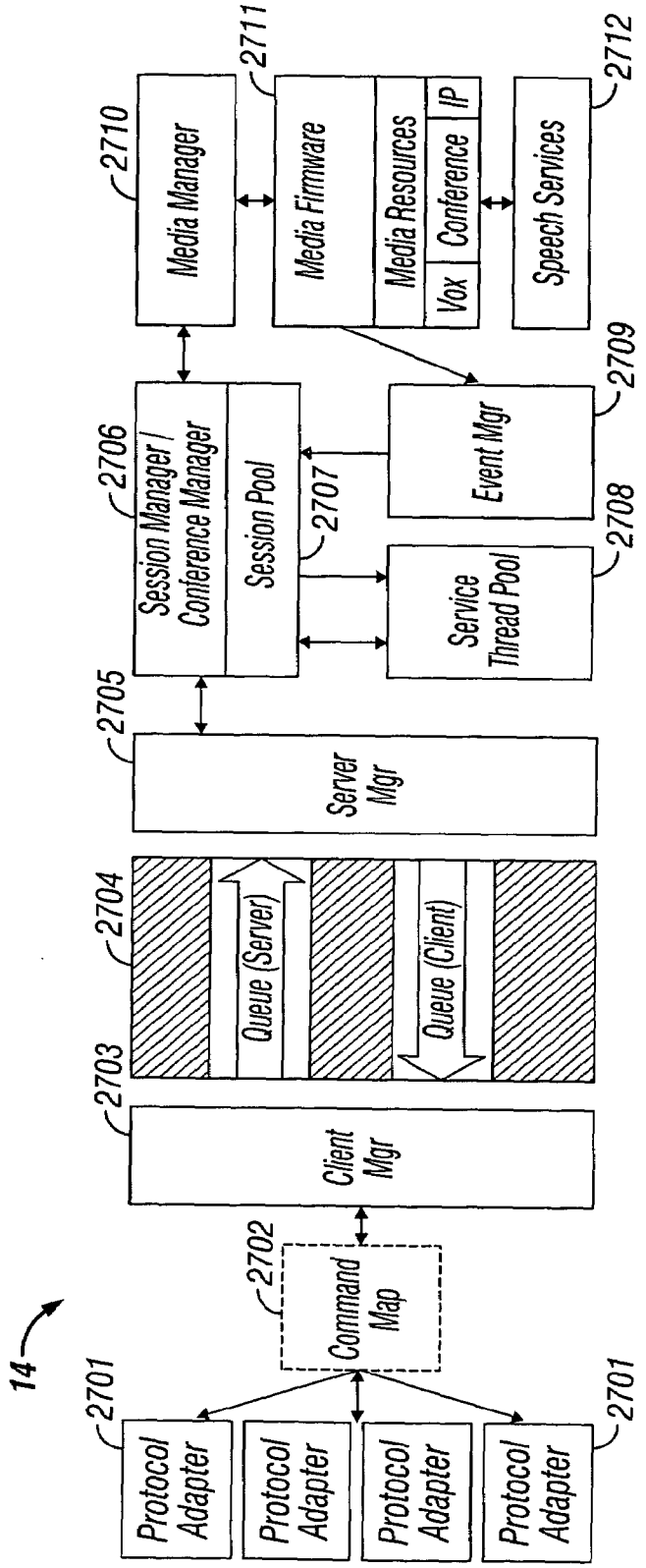

14
2701
Protocol Adapter
Protocol Adapter
Protocol Adapter
Protocol Adapter
2701
2702
Command Map
2703
Client Mgr
2704
Queue (Server)
Queue (Client)
2705
Server Mgr
2706
Session Manager / Conference Manager
Session Pool
2707
Service Thread Pool
2708
Event Mgr
2709
2710
Media Manager
2711
Media Firmware
Media Resources
Vox
Conference
IP
2712
Speech Services

FIG. 27

APPLICATION SERVER SYSTEM AND METHOD

FIELD

The present invention relates to platforms for developing or hosting telecommunications applications of various types.

BACKGROUND

There are a variety of computer platforms that host telephony applications. Such applications include voice mail messaging and multi-party calls, and many others. IP telephony (internet protocol telephony) applications introduce the telephone as a node on the IP network. In addition to point-to-point calling, telephones can serve as the origin or destination of a variety of network services. Further, telephones are no longer limited to voice communications or touch-tone menus. Modern IP phones sport rich interfaces with interactive touch-screen color displays.

There is, however, a limited selection of applications available for use on such phones. Such lack of applications stems partly from the expensive architectural upgrades Installing a new feature, such as voice mail, meant purchasing expensive new hardware for each circuit.

As a consequence, telephony applications appeared first at the edges of the network, in small offices or remote communities. Such proliferation helped catapult the rise of the PBX, or Private Branch eXchange, as the internal telephony interconnect within a building or organization.

A PBX originally served two purposes. First, it permitted a large number of end-users to share access to a small number of outbound lines. Second, it connected internal users without having to make a complete circuit to the telephone company and back. As the PBX became more powerful and commonplace, it began to include additional services such as call forwarding and voice mail. The increasing number of PBX vendors helped drive costs down but also resulted in each vendor utilizing proprietary systems for application development, making application development for widespread use prohibitively expensive.

Two principal issues plague application development for PBX systems. First there is the lack of standards in programming language, development environment, and signaling protocols. Communication with PBX hardware often involves closed, proprietary signaling protocols. Second, most PBX systems have extensibility and scalability problems.

In the 1980's and 1990's, the industry worked to resolve this issue with the development of a standard for telephony application development: TAPI, the Telephony Application Programming Interface. TAPI and its successor, JTAPI, (Java TAPI) are difficult to use since they required developers to have a deep understanding of the telephony switching to perform even the most basic functionality. Consequently, many developers and IT organizations avoided the standard and continued to invest in vendor-specific PBX systems.

The gradual adoption of Voice over Internet Protocol (VoIP) technologies in recent years helps reduce networking costs and potentially bridge voice and data networks. Modern VoIP PBX systems can communicate with IP telephones using the same data network shared by computers. However, such VoIP PBX systems continue to lack sufficient programmability, flexibility, and scalability. Further, modern VoIP protocols add to the number of protocols that application developers need to employ to be widely compatible.

What is needed, therefore, is a telephony application platform that enables communication over a variety of protocols

with a scalable application server. What is also needed is an application development environment that enables easy development across multiple protocols for the same application platform.

SUMMARY

An application server system is provided having a core engine connecting one or more protocol providers to one or more applications. In a preferred embodiment, the one or more applications run on a respective one or more virtual machines having their own execution threads. A thread pool may be used to spawn instances of applications or scripts. Preferably, the core engine, the protocol providers, and each of the one or more virtual machines run in separate AppDomains.

In another embodiment, a visual designer is provided having a design canvas for visually building applications. The visual designer converts the applications into XML versions for installation on an application server. An assembler process is provided for to assemble and install the application. A preferred embodiment has a debug interface to the application server is provided

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** depicts a high level block diagram of a communications environment according to a preferred embodiment of the present invention.

FIG. **2** depicts a block diagram showing module design of application server **12** according to a preferred embodiment of the present invention.

FIG. **3** depicts a block diagram of primary functional components of an application server core engine and other modules according to one embodiment of the present invention.

FIG. **4**A depicts an exemplar triggering criteria table according to one embodiment of the present invention.

FIG. **4**B depicts a messaging flow diagram according to one embodiment of the present invention.

FIG. **4**C depicts another messaging flow diagram according to one embodiment of the present invention.

FIG. **4**D depicts a call messaging flow chart of a SIP (session initiation protocol) call setup according to one embodiment of the present invention.

FIG. **5** depicts a flow chart showing an application lifecycle according to one embodiment of the present invention.

FIG. **6** depicts a block diagram of the structure of applications within the Metreos Communications Environment according to one embodiment of the present invention.

FIG. **7** depicts an abstract grouping of event types according to one embodiment of the present invention.

FIG. **8** depicts an event signature scheme according to a preferred embodiment of the present invention.

FIG. **9** depicts a flow chart of a provider action scheme according to one embodiment of the present invention.

FIG. **10** depicts a flow chart for a synchronous provider action according to one embodiment of the present invention.

FIG. **11** depicts a flow chart for an asynchronous provider actions according to one embodiment of the present invention.

FIG. **12** depicts a flow chart for a native action according to one embodiment of the present invention.

FIG. **13** depicts a flow chart for a core action according to one embodiment of the present invention.

FIG. **14** depicts an organizational block diagram of functions and data according to one embodiment of the present invention.

FIG. **15** depicts a state machine diagram of execution of a script instance according to one embodiment of the present invention.

FIG. **16** depicts script instances according to a preferred embodiment of the present invention.

FIG. **17** depicts a screenshot from a visual designer according to a preferred embodiment of the present invention.

FIG. **18** is a partial view of one screen of visual designer according to one embodiment of the present invention.

FIG. **19** depicts a graphical user interface screenshot for a visual designer according to one embodiment of the present invention.

FIG. **20** depicts a block diagram of components of the graphical user interface depicted in FIG. **19**.

FIG. **21** depicts a structural block diagram of a visual designer according to a preferred embodiment of the present invention.

FIG. **22** depicts a flow diagram of a typical usage scenario of a visual designer according to one embodiment of the present invention.

FIG. **23** depicts a flow chart of an approach for using a multiple view capability to build scripts according to one embodiment of the present invention.

FIG. **24** depicts a flow chart of using a web services integration capability according to one embodiment of the present invention.

FIG. **25** depicts a flow chart for a process of installing an application on application server according to a preferred embodiment of the present invention.

FIG. **26** depicts a flow chart of a debugging process according to one embodiment of the present invention.

FIG. **27** depicts a block diagram of a media server **14** according to a preferred embodiment of the present invention.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

FIG. **1** depicts a high level block diagram of a communications environment according to a preferred embodiment of the present invention. The Metreos Communications Environment (MCE) **10** is a feature-rich platform for developing and hosting IP telephony applications. At the core of MCE **10** is a powerful application server **12**, which controls media and external resources under the direction of custom telephony applications. MCE **10** provides control of a scalable software-based media server(s) **14** which processes, mixes, analyzes, and routes digital data such as, for example, audio data. Visual designer **16** allows developers to create complex telephony applications through a graphical design and deployment interface. System administrators manage MCE **10** through a web-based interface referred to as the system control panel **18**. These items will be further described with regard to later-referenced figures.

FIG. **2** depicts a block diagram showing module design of application server **12** according to a preferred embodiment of the present invention. Application server **12** serves as the core component of MCE **10**. Within application server **12** reside all installed applications **20**, which each include one or more scripts **22**. Application server **12** further includes a virtual machine **24** for executing applications **20** and a provider framework **25** having a variety of protocol provider modules **26** which extend the capability of the platform to reach third-party components.

Applications **20** designed for MCE **10** reside within an application pool or script pool in application server **12**. The platform provides automatic management of application state, handles side-by-side existence of varying application versions, supports seamless installation of new applications and trouble-free un-installation of any application not currently in use.

The software-based media server **14** provides the full functionality of hardware-based media servers **14** but with a pure software implementation. Inherent in this software-only design is the ability to automatically keep pace with inevitable advancements in processor speed and capabilities. Further, the design provides interoperability with standard telephony and networking protocols, such as RTP (real-time transport protocol), as well as scalability and redundancy through multiple media server **14** installations on parallel servers.

In this embodiment, each media server **14** installation supports up to 120 simultaneous connections, which equates to dozens of simultaneous user sessions spread across various applications. In this embodiment, as many as eight media servers **14** may be paired with one application server **12**. Such scalability provides ability to handle additional service levels by simply adding additional media servers **14**.

Preferably, media server **14** includes a variety of powerful features to enable complex telephony applications, including support for media streaming, DTMF (dual tone multi-frequency) interpretation, multi-party conferencing and recording. Other features may be included in media server **14**, such as, for example, text-to-speech, speech recognition and Voice XML (extensible markup language) support. Media server **14** will be further described with regard to later referenced FIG. **27**.

In this embodiment, MCE **10** simplifies the process of developing and deploying applications through use of visual designer **16**. Developing an application with visual designer **16** preferably does not involve paging through extensive lines of program code, and preferably does not require a deep understanding of call control or media processing. Instead, visual designer **16** presents a graphical user interface canvas **202** (FIG. **19**) where application components may be created and interconnected using a mouse or other pointing device. Finished applications can be deployed to MCE **10** via a menu selection or uploaded using the system control panel **18** as further described with regard to later referenced Figures.

Applications **20** may communicate with telephony interfaces (including voice over IP) and other communications interfaces via protocol provider modules **26**. Such interfaces or modules may be third-party systems. Protocol provider modules **26** may interface over various protocols such as, for example, an H.323 provider for first-party call control, a TAPI (telephony applications protocol interface) provider for third-party call control, an HTTP provider for network communication, a Timer provider for creating event-driven delays, a Cisco DeviceListX provider for caching CallManager device information, and finally a Media server provider for communication with media server **14**.

Examples of applications which may employ such protocol provider modules **26** are:

Microsoft Exchange™ Integration: Provide alerts when meeting events occur by ringing users on their mobile phones.

Instant Messaging and Collaboration Integration: Start collaborative conference calls from instant messaging sessions.

Voicemail: Provide customized, flexible voicemail services to meet individual organizational needs.

Conferencing: Employ media server **14** to support instant recordable conferencing with participant mute and kick.

Click-To-Talk: Extend a desktop PIM (personal information manager) client (such as Microsoft Outlook™) with a protocol provider **26** to enable one-click calling between parties in the PIM's address book.

Location-Based Forwarding: Integrate with enterprise IT authentication system to automatically forward incoming calls to a user's home phone, mobile phone, desk phone, or forward based on a user's presumed location from the system login trail.

Referring still to FIG. **2**, in this embodiment, system control panel **18** permits administrators to manage the configuration of MCE **10**, install and remove applications **20** and provider modules **26**, and control other aspects of operation.

Application server **12** handles communication between components, processes user input, controls the media servers **14**, and provides interfaces for the system control panel **18** and visual designer **16**. The primary functional units of application server **12** are preferably grouped into subcomponents. In this embodiment, such subcomponents include script pool **19**, assembler **28**, OAM (operations and maintenance) module **29**, provider framework **25**, virtual machine **24**, and core engine **27**. Each element communicates with other components through a messaging infrastructure controlled by the core engine **27**. Such interconnection is depicted with arrows drawn between each component and the Core engine **27**.

Applications **20** within MCE **10** interact with the outside world through protocol providers **26** ("providers **26**"). Providers **26** offer a family of services typically associated with a communication protocol. Providers **26** may open network ports and allow the Application Server **12** to communicate with numerous other devices on a network. For example, the HTTP provider enables applications to accept incoming web traffic and respond accordingly, or make HTTP requests to other hosts elsewhere on the network.

Providers **26** preferably execute within their own virtual process space and facilitate communication between application server **12** and external systems. Preferably, providers **26** are the sole means in which applications may execute asynchronous operations and are the only sources for unsolicited events. Such events will be further described referring to later Figures. Typically, a protocol provider **26** utilizes an underlying protocol stack and then implements an API layer to translate the action and events flowing to and from Application Server **12**'s core engine **27** so they conform to a defined interface.

In this embodiment, providers **26** have two primary functions. First, they must respond to actions received from applications executing within application server **12**. Secondly, they handle data received from external services and generate events to be handled by applications **20** within application server **12**.

Provider framework **25** is preferably a well-defined API (application protocol interface) that enables third-party developers to build extensions to MCE **10**. By implementing the interfaces defined within provider framework **25**, developers may extend Metreos Communications Environment **10** to external systems or protocols.

In this embodiment, OAM module **29** handles communication with system control panel **18** and visual designer **16**. Using OAM component **29**, MCE **10** exposes a management API that may be employed to integrate third-party network management tools.

In this embodiment, assembler **28**, working in conjunction with the core engine **27**, prepares new applications **20** for use by application server **12** by distributing application components across MCE **10**. This includes separating out scripts **22**, databases, media resources and the installer from each new application **20**, and performing initial tests for correctness and resolving any versioning issues. Scripts **20**, databases, and media resources will be further described with reference to later Figures. Preferably, once an application **20** has been extracted and tested for data integrity, assembler **28** takes each script **22** contained within the application **20** and transforms the XML intermediate language into instructions executable by virtual machine **24**. During this step the assembler checks the syntax of the intermediate language to ensure the script is well-formed. Assembler **28** then signals the core engine **27** that application **20** is valid. Core engine **27** then prepares any application databases. If an application installer is present, it is executed, setting up any configuration parameters for application **20** and setting default values as provided by the developer. Also, core engine **27** negotiates procurement and provisioning of any media resources, so applications **20** which need to play audio through Media servers **14** will have assured access to these files. Finally, assembler **28** passes on scripts **22** associated with application **20** to script pool **19**.

Preferably, application scripts **22** reside within script pool **19** fully prepared for execution. Script pool **19** is notified by the core engine **27** when it is time to start executing a particular script **22**. Core engine **27** makes this determination by comparing incoming events from protocol providers **26** with triggering criteria defined for the installed scripts **22**. Once core engine **27** informs script pool **19** that an event has come in for a particular script **22**, script pool **19** passes a copy of the script **22** to virtual machine **24**. Such a copy is called a script instance.

In this embodiment, virtual machine **24** manages the running code of any active applications **20**. In a preferred embodiment, multiple instances of virtual machine **24** are employed (FIG. **3**). Within the constraints of system resources, any number of scripts **22**, each with any number of script instances, may be executed simultaneously. Such capability ensures that multiple applications **20** may run in parallel, and that multiple users may be accessing any one application **20** at the same time. Virtual machines **24** also ensure system stability by segmenting applications **20** from one another. This segmentation mechanism helps ensure that an unstable application **20** cannot adversely affect other applications. Preferably, once virtual machine **24** determines that an application **20** is in an unstable state, the application **20** is unloaded and will not trigger again until the problem is resolved and the application **20** is reinstalled. Other error control mechanisms may be used. For example, an unstable application **20** may be terminated but other instances allowed to run. An application error log may be used to alert administrators of applications **20** that exhibit excessive instability.

In this embodiment, all communication between components, as well as subcomponent control and resource management, occurs within core engine **27**. In addition, core engine **27** preferably manages other application components.

FIG. **3** depicts a block diagram of primary functional components of an application server core engine **27** and other modules according to one embodiment of the present invention. Preferably, each boxed component represents a thread, with a few exceptions. The solid lines with arrows represent the flow of inter-thread messaging. The direction of the arrow indicates which component typically initiates the communication. The module or component receiving recipient may transfer data back in response. Implementation of such thread messaging is known in the art and may be accomplished by employing, for example, shared variables in a common address space.

In this embodiment, application server **12** is built with Microsoft's .NET development platform. The dotted lines represent AppDomain boundaries in a preferred architecture. An AppDomain is a capability of the .NET platform which enables creation of a virtual process boundary and then com-

municate across it. Other architectures may be used. For example, another preferred embodiment uses a similar application domain boundary capability of Java. Preferably, such architecture ensures that, if a component within an AppDomain crashes, the rest of the system remains stable. In this embodiment, the AppDomain boundaries are placed such that they isolate core engine **27** from the protocol providers **26** and applications **20**.

In this embodiment, core engine **27** has provider manager **304**, which is preferably a sub-component of Action/Event Router **302**. Provider manager **304** is responsible for instantiating and managing protocol providers **26**. Preferably, application server **12** is not limited to a particular number of protocol providers **26**. Core engine **27** is typically not aware of what protocol providers **26** will be loaded. Instead, when the Application Server **12** starts, provider manager **304** searches the 'providers' directory for assemblies (preferably dynamic linked libraries, DLLs) which conform to a well-defined protocol provider API. When provider manager **304** finds a suitable assembly, it loads the assembly. Likewise, protocol providers **26** may be loaded or unloaded at any time via the system control panel **18**.

Preferably, provider manager **304** is also responsible for distributing actions to the proper provider **26** by way of namespaces. For example, a provider **26** may start up and register the namespace "Metreos.Providers.H323" as its namespace. When the provider manager receives the action "Metreos.Providers.H323.MakeCall", it is programmed to send the action to the provider registered with the "Metreos.Providers.H323" namespace.

Core engine **27** and applications **20** are not typically aware of any specific protocol provider **26** API ahead of time. Protocol providers **26** preferably use attributes to describe the actions and events they can handle to applications **20** through core engine **27**. Preferably, users are provided with a tool which inspects provider **26** assemblies and generates an XML file for each provider **26** which describes the provider's API based on the attributes in the code in the provider **26**'s assembly. Visual designer **16** then reads the XML file and generates icons for the actions and events described therein. Visual designer **16** will be further described with reference to later Figures.

Provider manager **304** also handles some basic system housekeeping such as pinging providers **26** to see if they have crashed and, if so, restarting them automatically.

Referring still to FIG. **3**, core engine **27** has action event router **302**. ("event router", "router"). Applications **20** specify to core engine **27** a set of criteria on which they are configured to trigger. Applications **20** preferably must trigger on an event. After an application **20** triggers, router **302** must retain state information for all instances of such application **20** so it can route all subsequent events properly until the instance terminates.

In order for router **302** to start and interact with applications **20**, applications **20** must register their triggering criteria. Such registration is preferably done when application **20** is installed or application server **12** is started. Router **302** preferably keeps track of the triggering criteria in a table. Such a table preferably lists parameter values or ranges matched with certain event types and applications.

FIG. **4**A depicts an exemplar triggering criteria table according to one embodiment of the present invention. The "Incoming Event" column describes the event received by router **302** for handling. The other columns describe applications **20** which are registered to handle various permutations of this event. Preferably, router **302** may only select one application **20** to trigger, so it will pick the best match. In a preferred embodiment, router **302** chooses the best match as being the application that has the most matching parameters to the trigger event, and has no mismatching parameters.

For example, the best match for the incoming event in FIG. **4**A is App**2** because it has more matching parameters than App**1**, and App**3** has a mismatched parameter. In this exemplar, if App**2** did not exist, App**1** would be triggered since it would have the most matching parameters without any mismatches. Other application triggering algorithms may be used.

FIG. **4**B depicts a messaging flow diagram according to one embodiment of the present invention. In this exemplar diagram, an application **20** first registers its triggering criteria with router **302**. Some time later, a protocol provider **26** initiates a session. When an HTTP message is received on the HTTP stack, the provider creates a "GotRequest" event with all the associated parameters and a newly-generated Routing GUID (globally unique identifier) and sends it to router **302**.

In this example, router **302** does not yet recognize the Routing GUID, so it matches the event to an application **20** based on the criteria specified in its routing tables (FIG. **4**A). Router **302** then forwards the event to the virtual machine **24** where the selected application **20** resides. The selected virtual machine **24** ("virtual machine", "application runtime", "application runtime environment") then creates a new instance of the script **22**, seeds it with the incoming event information, and begins executing it. Virtual machine/application runtime **24** will be further discussed below.

At some point in script **22**'s execution, it decides to send an action to the HTTP provider **26**. Preferably, the application **20** is not limited to using only the provider **26** which triggered it. Since the action is routed based on namespace, the application may issue actions to any and all providers it wishes. In this example, application **20** sends an action to HTTP provider **26**. Provider manager **304** matches the namespace and forwards the action. Typically a provider **26** is obligated to send a response to any received actions. In this case, provider **26** sends "Success".

As another exemplar, if provider **26** were to send some other event which needed to go to this script **22** instance, it would reuse the same Routing GUID. In preferred embodiments, when router **302** receives an event with a Routing GUID it has seen before, it forwards the event on to the corresponding script **22** instance previously associated with the GUID.

In this exemplar, when script **22** has finished everything it needs to do, it terminates itself with an "EndScript" action. This action signals application runtime **24** to reset all session state associated with this script instance, return it to the script pool **19**, and send a message to router **302** indicating that the script is no longer running. When router **302** gets the message that script **22** is ended, it removes all session-related information from its routing tables, but it retains the triggering information so it can start new instances of script **22**. Preferably, only when the application **20** is uninstalled does router **302** remove the triggering criteria for each of the application **20**'s scripts **22** from the routing tables.

FIG. **4**C depicts another messaging flow diagram according to one embodiment of the present invention. In this exemplar, an application **20** initiates the communications session. In such a case, the provider preferably must store the Routing GUID, which is mechanically derived from an Action GUID associated with action from application **20**. Such a routing ID is for use in subsequent events destined for the script **22** instance which generated the Action. This scenario may occur if a script **22** is triggered by an event from another provider **26** in application server **12**. In this case, multiple providers **26**

may be sending events with the exact same Routing GUID. Router **302** forwards them all to the script **22** instance in the same way.

Referring again to FIG. **3**, in this embodiment, administrators can configure application partitions, which are sets of data associated with a particular application **20**. Once an application **20** is installed, a default application partition is created. That partition contains the triggering information for each script **22** in the application **20** as specified at design time. Preferably, an administrator may then change or augment the triggering parameters. The triggering event name, however, preferably cannot be modified. Further, the administrator may specify a call control protocol to use when a script **22** triggered by the criteria in this partition wishes to use call control services. Examples of such protocols are H.323, SCCP, CTI (JTAPI), and SIP. Other protocols may be included if appropriate protocol providers are configured on application server **12**.

Configuration (config) component **310** is preferably a singleton class (not a thread) which exposes methods which are called directly by nearly all components in application server **12**. The config class acts as the core engine **27**'s gateway to a system config database. The config class is preferably the only component which has access to the config database. Such a scheme helps ensure that all database operations are thread-safe, atomic, and maintain referential integrity.

As an exemplar, when a provider **26** loads, it may wish to advertise a configuration value that an administrator can use to adjust provider **26**'s behavior. In such a case, provider **26** (by way of a standard base class) makes a call to the config class which tells it to add the config item. The config class then updates one or more database tables, keep track of database locks, and otherwise manage addition of the configuration item.

Referring still to FIG. **3**, in this embodiment, telephony manager **312** is interconnected with more than one virtual machine **24**. Other embodiments may have only one. Telephony manager **312** exposes a common API, preferably referred to as the CallControl API, for all call-control stacks in use with application server **12**. The CallControl API specifies a specific set of actions and events which a provider **26** must be able to handle in order to utilize telephony manager **312**.

As discussed above, providers **26** may define their own API which identifies the actions and events they can handle. In this embodiment, providers **26** which conform to the CallControl API implicitly declare all the actions and events contained in the CallControl API and thus only explicitly declare any actions or events which are proprietary to that provider **26**. Preferably, providers indicate that they wish to participate with the CallControl subsystem using a special flag when they register their namespace at load time. When Provider Manager **304** sees that a provider **26** has elected to participate in the CallControl subsystem, it notifies the Telephony Manager **312**, so it will know how to handle CallControl actions which are destined for the type of call control protocol specified.

In this embodiment, the application runtime **24** is programmed to forward all actions with the namespace "Metreos.CallControl" to telephony manager **312**. Likewise, router **302** forwards all events with the namespace "Metreos.CallControl" to the telephony manager **312**. Such a namespace represents a generic telephony service and other namespaces and access schemes may be used. When the telephony manager **312** receives an action, it looks up what call control protocol is configured for the application partition that sent this action. It then looks to see if a provider **26** has registered as a handler for that protocol. Once the associated provider **26** and its real namespace are identified, the telephony manager **312** translates the action name so it will be routed to the configured provider and then sends the action on to Provider Manager **304**.

As an exemplar, an action is received by the telephony manager **312** having parameters with values as follows: Action=Metreos.CallControl.MakeCall, AppPartition=NewYork, To=5124377913@callmanager.mycompany.com. The telephony manager **312** finds that the control protocol configured for the destination application's partition is H.323. A provider **26** registered as "Metreos.Providers.H323" claims to handle this protocol. So the telephony manager **312** translates the action to: Action=Metreos.Providers.H323.MakeCall. Telephony manager **312** leaves the rest of the parameters as they were and forwards the action to Provider Manager **304** for routing to the H.323 provider.

The telephony manager **312** preferably has the capability to handle an almost infinite number of possible combinations of actions and events and force them to conform to the common API. To provide such capability, this embodiment has a telephony manager **312** implemented as a script engine. Preferably, the telephony manager **312** script engine is hard-coded with handlers for the well-defined, finite set of actions which can appear in scripts **22** so no input parameters are necessary. Telephony manager **312** script engine keeps track of all the data it knows about a given call and includes as much relevant information as possible in the actions and events it generates.

In this embodiment, a scripting language is provided to for programming telephony manager **312**. Preferably, the scripting language provided is a state description language. A high-level definition of such scripting language is provided in several following tables. The language described is merely exemplary and other languages containing other syntax or features may be used to implement a telephony manager **312** in other embodiments.

Table 1 contains a list of the valid tags which can be used to start any line in a state description. Table 2 contains a syntax definition for the tags listed in Table 1. Table 3 contains the order in which next state conditions are evaluated by the execution engine. Usage recommendations follow each condition.

Table 4 contains preferred valid values for the data field. The field type follows the name in parenthesis. For uint fields, any uint value can be specified after the comparator (= or !=). For bool values, true or false can be specified. All other values can only be compared to null.

TABLE 1

Tag:	Function:
trigger	Declares the triggering action or event for the script
a	Action declaration. There can be only one
rns	Response Next State. Can use * wildcard to indicate any response
ens	Event Next State
ans	Action Next State
dns	Data Next State
def	Default next state. Only one allowed
timeout	Next state on timeout. Only one allowed

TABLE 2

Syntax:
event:[event name]
a:[action name]
(rns | ens | ans):[expected value]->[next state ID]
dns:[field name](= | !=)[field value]->[next state ID]
def->[next state ID]
timeout:[number of seconds]->[next state ID]

TABLE 3

Priority:	Notes:
1. Responses	Use only with timeout
2. Actions	Do not combine with responses, data, or default. Use timeout
3. Events	Do not combine with responses, data, or default. Use timeout
4. Timeout	Use only with responses, actions, and/or events
5. Data	Use only with default
6. Default	Use only with data

TABLE 4

Data Field:	Valid values for data fields:
callId	string
peerCallId	string
mmsId	string
connectionId	string
localMediaCapsSet	complex custom collection
remoteMediaCaps	complex custom colleciton
txAddr	IPEndPoint
txCodec	string
txFramesize	uint
rxAddr	IPEndPoint
rxCodec	string
rxFramesize	uint
waitForMedia	bool

FIG. **4**D depicts a call messaging flow chart of a SIP (session initiation protocol) call setup according to one embodiment of the present invention. Table 5 depicts a script designed for telephony manager **312** to implement the SIP call setup depicted in FIG. **4**D.

TABLE 5

```
1    trigger:Metreos.CallControl.IncomingCall
2
3    1
4    a:ForwardEventToApp
5    ens:GotCapabilities->5
6    ans:AnswerCall->[IncomingCall__LateMedia]
7
8    5
9    a:GetMediaCaps
10   rns:success->10
11   rns:*->205
12
13   10
14   a:SelectTxCodec
15   def->15
16
17   15
18   a:SetMedia
19   rns:success->20
20   rns:*->205
21
22   20
23   a:Wait
24   ans:AnswerCall->25
```

TABLE 5-continued

```
25
26   25
27   a:AcceptCall
28   rns:success->30
29   rns:*->205
30
31   30
32   a:ReserveMedia
33   rns:success->35
34   rns:*->205
35
36   35
37   a:SetMedia
38   rns:success->40
39   rns:*->200
40
41   40
42   a:ForwardActionToProvider // Forwards AnswerCall
43   rns:success->41
44   rns:*->46
45
46   41
47   a:Wait
48   dns:waitForMedia=false->45
49   def->50
50
51   45
52   a:ForwardResponseToApp
53   def->50
54   ans:Hangup->90
55
56   46
57   a:ForwardResponseToApp
58   def->200
59
60   50
61   a:Wait
62   ens:MediaEstablished->55
63   timeout:10->200
64
65   55
66   a:CreateConnection
67   rns:success->60
68   rns:*->200
69
70   60
71   a:SendStartTxToApp
72   def->65
73
74   65
75   a:ForwardResponseToApp
76   def->70
77
78   70
79   a:SendStartRxToApp
80   def->75
81
82   75
83   a:Wait
84   ens:Hangup->80
85   ans:Hangup->90
86
87   80
88   a:DeleteConnection
89   rns:*->85
90
91   85
92   a:ForwardEventToApp
93   def->1000
94
95   90
96   a:DeleteConnection
97   rns:*->95
98
99   95
100  a:ForwardActionToProvider
101  rns:*->100
102
103  100
```

TABLE 5-continued

104	a:ForwardResponseToApp
105	def->1000
106	
107	200
108	a:DeleteConnection
109	rns:*->205
110	
111	205
112	a:SendHangupToApp
113	def->210
114	
115	210
116	a:HangupCall
117	rns:*->1000
118	
119	1000
120	a:End

Referring again to FIG. **3**, in this embodiment, application server **12** has an assembler/application manager **28** for installing and configuring applications **20**. Assembler **28** will be further described with reference to later Figures.

In this embodiment, application server **12** has a management interface **308**. Preferably, management interface **308** listens on a socket and accepts TCP connections from system control panel **18** (FIG. **1**). Control panel **18** uses this interface primarily to notify core engine **27** of changes to the Application Server **12** configuration via XML messages. In a preferred embodiment, management interface **308** exposes the following functions:

Execute provider extensions (proprietary methods published by providers at load-time.)
Enable/Disable Applications
Install/Uninstall Applications
Enable/Disable Providers
Install/Uninstall Providers
Add/Remove Media Servers
Add/Remove CallManager clusters
Add/Remove Log Sinks

Referring still to the preferred embodiment depicted in FIG. **3**, application server **12** has virtual machines **24**. Virtual machine **24** is the component that starts, executes, terminates, and manages application script **22** execution. Virtual machines **24** execute inside a child AppDomain **21**, indicated on the diagram as bordered by dotted lines. The diagram shows two copies of virtual machine **24** for exemplar purposes. In a preferred embodiment, there are as many virtual machines **24** on an application server **12** as there are applications **20** installed on that application server **12**. When there are no applications installed, there are no virtual machines **24** present. There is preferably no set limit to the number of applications (and thus virtual machines **24**) which may be loaded. Virtual machines **24** will be further described with regard to later referenced Figures, especially FIGS. **15** and **16**.

The embodiment in FIG. **3** also has a logger component **314** to manage log messages. Preferably, logger **314** is closely tied to .NET tracing functions and uses .NET trace listeners to route log messages to various log sinks based on configurable criteria. Another preferred embodiment uses a Java implementation. The log sinks included with the Application Server **12** are preferably as follows:

Console Logger (writes logs to the console (stdout))
File Logger (writes logs to a file)
Event Logger (writes log to the Windows event log)
Remote Console (writes logs to any number of TCP connections)
Debug Logger (writes logs to the Windows debug queue.)

The list of log writers is preferably extensible. A new logging assembly which implements a well-defined log sink interface may be deployed via the system control panel **18** management website. The website places the assembly into a configured directory and the Application Server **12** startup process picks it up via a directory watcher and installs it.

FIG. **5** depicts a flow chart showing an application lifecycle according to one embodiment of the present invention. Applications **20** typically begin their existence in the integrated development environment of visual designer **16**. As an application evolves, developers will iteratively test the program by compiling and executing the application **20**. MCE **10** provides a process having, in this embodiment, five distinct steps, which are described here as an overview and later further detail.

In step **1**, development, application is created in visual designer **16** development environment. In step **2**, build, visual designer **16** prepares application for use by converting diagrams into a proprietary XML-based intermediate language, and then compiled code and additional application data (such as media resources, an installer, and any needed databases) are combined into a single archive file. In step **3**, deployment, the archive file is uploaded to application server **12**, either through system control panel **18** or via direct deployment in visual designer **16**. In step **4**, installation, the archive is unpackaged and resources are allocated to handle all components of the new application **20**. Application scripts **22** are copied into script pool **19** where they wait for events. In step **5**, execution, application server **12** processes the application **20** generated from the user's initial design.

Each of these five steps occur in different locations throughout the MCE **10** platform. Some steps may involve two or more components.

Referring still to the embodiment depicted as a flow chart in FIG. **5**, an application **20** preferably begins its existence (step **1**) in visual designer **16** where the application logic is formed. Visual designer **16** will assist the programmer by applying certain rules automatically to ensure that applications **20** are well-formed. For example, if a developer drops an action on the canvas which generates callback events, visual designer **16** will automatically generate functions for the developer to use when implementing those event handlers. Development in visual designer **16** will be further described referring to later Figures.

Once the developer has completed application **20**, or completed enough application components to test some aspect of functionality, they instruct visual designer **16** to "build" or compile application **20** (step **2**). Such building converts application **20**'s representation as data and logical flow from a visual representation of boxes and arrows to a linear description in an XML-based proprietary intermediate language. Functions which lack proper exits, uninitialized variables, or unspecified execution paths will all cause errors to appear during compilation.

In this embodiment, after the application **20** is successfully compiled into XML, all XML code and other application components are packaged into a single unified archive file. Such a packaging process simplifies transporting applications **20** and related data by rolling everything into a single file, including databases, media resources, installer information, the application, custom code, and related versioning data. In a preferred embodiment, the archive files retain the extension .MCA, for Metreos Communications Archive. Packaging may be accomplished through visual designer **16**, or through a packager command line tool.

Packaging errors can occur when the additional resources such as installers, databases, custom code and media resources appear malformed or contain conflicting information. While the packager typically cannot catch all possible errors, many types of resource problems can become evident during step **2**.

Referring to deployment (step **3**), packaged archives are preferably installed to the application server **12** either through visual designer **16** or system control panel **18**. Application server **12** receives the archive through OAM component **29**, which handles all configuration and administrative communications. OAM component **29** in turn routes the complete package to the assembler **28**, which unpacks the contents and routes individual components throughout application server **12**. Assembler **28** prepares a memory map (an executable version of application **20**) using an assembly process described in more detail later.

The installation or assembly step (step **4**) unpacks the archive file and prepares its elements for provisioning throughout the system. Any databases in the package arrive in the core engine **27**, which determines based on versioning data whether or not existing databases from previous installations will affect this install. Then, core engine **27** attempts to create or update the data and schemas defined by the new application **20**. Such a creation process could return database creation errors which result from malformed SQL (structured query language), or resource allocation problems from overloaded application servers **12**. Preferably, installers are routed to core engine **27** and immediately processed. Syntax errors or unsupported installer commands generate errors, which are then returned to the user through OAM component **29**.

During installation, media resources are preferably likewise passed along to core engine **27**. Core engine **27** in turn contacts the media servers **14** associated with the respective application server **12**. To ensure optimum performance, all such media resources are preferably installed on each media server **14** in the particular MCE **10**. In another embodiment, media files may be stored on a centralized repository or file server. Core engine **27** may report problems if the media servers **14** lack sufficient resources to store the media files, or if the server(s) are not reachable.

In this embodiment, script pool **19** registers each script **22** with core engine **27** in order that appropriate incoming events can initiate script execution. This registration process ends the Installation Phase.

In step **5**, each time an event fires whose event signature matches a script **22**'s triggering event signature, the corresponding script **22** is executed by virtual machine **24**. Any number of instances of the same script **22** may be created, within configuration and resource limitations. Each instance maintains separate memory storage and distinct access to resources.

During execution, any detected runtime or logic errors are preferably logged in an application server log. When a script instance finishes execution, relevant state information is reset and it returns to script pool **19** awaiting the next triggering event. Other embodiments may work with temporary copies of scripts **22**.

FIG. **6** depicts a block diagram of the structure of applications within MCE **10** according to one embodiment of the present invention. Applications **20** preferably contain a wide variety of elements, organized according to strict architectural requirements. Applications **20** within MCE **10** are typically referenced by name. The application name provides basic descriptive information to users and developers of the nature and capabilities of the application service.

In this embodiment, each application **20** consists of up to four types of components: scripts **22**, an installer **62**, databases **64**, and media resources **66**. The latter three component types are optional and may be included in any combination to meet an individual application **20**'s requirements.

Preferably, all application logic either occurs within scripts **20**, or is directed by scripts **20**. Use of scripts **20** gives programmers the ability to alter execution paths with control structures **67**, store data in script-wide or function-scope variables **68**, access external resources, and indirectly accept input from users.

An application may have a single installer **62** containing instructions to direct installation. In a preferred embodiment, installer **62** is represented as an XML configuration file, which preferably is automatically prepared by the visual designer **16** upon request. Application developers may wish to include special instructions to MCE **10** regarding the desired setup and deployment of their services. Such instructions may concern requirements like dependencies on external protocol providers **26**, configuration settings, and licensing restrictions.

Databases **64** provide applications **20** ability to retain data beyond the execution of an individual script **22**. Applications **20** within MCE **10** may include any number of associated SQL (structured query language) databases **64** which enable developers to store relational data in application **20**. Information stored within databases **64** persists across any downtime periods or other connectivity issues which can occur, making databases **64** particularly useful for storing long-term data such as call records, access permissions and other general storage items.

MCE **10** preferably has an embedded SQL engine designed for high-speed retrieval of data for use in high-performance telephony applications. For applications requiring report generation, integration with existing databases, or other advanced database features, MCE **10** may also provide connectivity to remote data stores through an external collection of classes such as ADO.NET (activeX data objects) classes, in addition to using the embedded database engine. Such connectivity is provided in another preferred Java embodiment with the JDBC API (Java Database Connectivity).

Media resources **66** contain data regarding media items such as audio prompts. Examples of such media resources are pre-recorded greetings, error messages, and status messages. MCE **10** lets developers bundle any necessary audio prompts with an application, easing the deployment process further. Preferably, media resources **66** are .vox or .wav files. Any number of files may be included within an application **20**. In a preferred embodiment, such files are 8 bit/8 khz, to maximize performance.

FIG. **7** depicts an abstract grouping of event types according to one embodiment of the present invention. In a preferred embodiment, the structure of the application server **12** relies upon a programming paradigm called the action-event model. In MCE **10**, applications **20** respond to events and communicate through actions. The action-event model, instead of polling a resource over and over again for new data associated with an event such as an incoming call, automatically executes code associated with the event. In a preferred embodiment, an event is implemented as an inter-thread message created by a protocol provider **26** to indicate some sort of event occurred, which an application may be interested in. Such a message includes all relevant parameters and a Routing GUID (globally-unique identifier) which core engine **27** uses to correlate application sessions. A triggering event is one where the Routing GUID is new. Subsequent non-triggering events utilize the same Routing GUID as the original

event. For example, "IncomingCall" would be a triggering event, whereas "Hangup" would be non-triggering. Events do not require a response.

MCE **10** monitors a variety of events which may arise. Such events include telephone calls, HTTP messages, and announcement status information, among others. When these occurrences manifest within MCE **10**, an event is generated. Examples of events include CallControl.IncomingCall, and Providers.Http.GotRequest. Any number of events may fire simultaneously, and of course a single event may fire in rapid succession. Programs within the MCE typically respond to a small subset of the possible events which may be raised, but developers can select any combination of events based on business requirements.

Events originate from protocol providers **26** and reach applications **20** by way of the event distributor or router. Such a router is preferably part of core engine **27**. A preferred embodiment of core engine **27** including a router or event distributor is further described with reference to FIG. **3**.

In this embodiment, MCE **10** presents three distinct types of events to developers, with a fourth hybrid type for technical completeness. The three fundamental event types are triggering events, unsolicited events, and asynchronous events. Some events may be used as both triggering events and unsolicited events, even within the same application. These are called hybrid events. Typically, no asynchronous events occur as triggering or unsolicited events.

For each script **22** within applications **20**, one particular triggering event **72** starts the script **22**. MCE **10** preferably generates new script instances automatically each time a triggering event **72** occurs. Each script instance preferably operates independently of other scripts, so script state and script-level variables are automatically preserved. Preferably, MCE **10** will not execute an application **20** if it finds more than one application **20** with the same triggering event parameters.

Unsolicited events **74** can occur at any time during script **22** execution. Such events typically indicate an action which was taken by an external user. For example, a script which triggers on CallControl.IncomingCall must be prepared to receive the CallControl.Hangup unsolicited event at any time. Script designers may anticipate, however, multiple unsolicited events of the same type. For example, if a script **22** places several calls, multiple CallControl.Hangup unsolicited events may occur. If each event needs to be handled differently, script **22** may have branching code to properly interrogate each event signature and follow the necessary course of action. Such branching is one use of the userData parameter in actions which generate unsolicited events. MCE **10** automatically propagates information about parameters such as the userData information back to the event handler.

Asynchronous events **76** differ from unsolicited events in that they typically occur only after a corresponding action has executed. For example, calling the action MediaServer.PlayAnnouncement will attempt to play an audio stream to a specified destination. If the media cannot be played for any reason, within a fraction of a second the MediaServer.PlayAnnouncement_Failed event will respond back to the same script which made the request. However, if the announcement was played successful, the MediaServer.PlayAnnouncement_Complete event will occur. These two callbacks will not occur before the MediaServer.PlayAnnouncement action has executed, and one or the other is guaranteed to occur if the action executed successfully. This differs from unsolicited events which may not ever occur depending on the circumstances.

FIG. **8** depicts an event signature scheme according to a preferred embodiment of the present invention. The unique identification of particular event parameters used to initiate a function is called an event signature. In preferred embodiments, every time an event fires, functions associated with that event are invoked if and only if they corresponding event signature matches. These functions are called event handlers. The event handler scheme provides a programmatic way for event routing to occur within the architecture, rather than within applications. Such a scheme enables MCE **10** to handle the load-balancing, failover, and performance requirements of a deployment distributed across multiple server machines.

In the example depicted in FIG. **8**, event **82** may have different combinations of associated parameters. Such parameters are compared with event signatures **84** to find the closest event signature. A match if forwarded to the event handler **86** associated with the closest event signature. An event handler may be defined for an exact range of parameters of interest. Such a range of parameters may be matched with a particular event signature. For example, if a script **22** should only begin when calls are placed to a particular set of phone numbers, the firing event can be interrogated to see if it matches the signature set of phone numbers needed by script **22**. Expressions such as, for example, regular expressions may also be used to specify event signatures.

Events within MCE **10** may also be characterized according to a protocol session scheme. Such a scheme groups activities that are related by one common element, often the same user or user agent. For example, a visit to a website might constitute a session with a clear beginning and end, and data exchanged throughout. Similarly, the collection of TCP/IP packets transmitted to download a single image on one page of that visit might also be considered a session. Generally speaking, protocol providers within MCE **10** may present some concept of a session. The start of a new session is typically associated with a triggering event **72**. Events which arise during the course of a session and are handled by applications **20** are either unsolicited events **74** or asynchronous events **76**.

The complimentary component to events, actions, are used to send data outside of MCE **10** or carry out specialized application logic. An action is preferably an inter-thread message generated by the application runtime environment **24** on behalf of a script **22**. The message contains the action name and all parameters specified in the script **22** in addition to an Action GUID. An Action GUID is preferably a concatenation of the Routing GUID which triggered this session and the Action ID. All actions preferably require responses. A provider, or some component in the core, must send a response of some sort (usually "success" or "failure") upon receiving an action. Like an action or event, responses are similar inter-thread messages. Application scripts **22** are typically constructed using conditional logic by linking together one or more actions. In a preferred embodiment, there are two main categories of actions: provider actions and native actions.

FIG. **9** depicts a flow chart of a provider action scheme according to one embodiment of the present invention. Provider actions **92** flow out of an application **20** into provider framework **25**. Provider events **94** bring messages from providers **26** back to applications **20**. Information may flow in both directions when a provider action **92** is called by an application script. Information typically flows in only one direction, however, when a provider event **94** occurs.

Typically, calling a provider action **92** blocks script **22**'s execution until a response is returned. This sequence is indicated by the two execution arrows directly below the provider actions **92** in the diagram. Simple actions which only involve this execution path are called synchronous actions. However,

some calls to a provider action may only be able to offer a provisional response. In such a case, the final response occurs later in the form of asynchronous event. This class of action is called an asynchronous action.

FIG. **10** depicts a flow chart for a synchronous provider action according to one embodiment of the present invention. Synchronous provider actions **102** represent a request-response transaction within the application server **12**. First, action **102** is invoked from a particular location within an instance of script **22**. Such invocation is called a request, which is passed to the associated protocol provider **26** for handling. When the provider is finished processing the message or an error occurs, an action response message is sent back to the specific script **22** instance that sent the original request, and script processing continues.

Preferably, from the time the original action request is sent until the time a response is received, the script instance **22** is in a wait state pending a response to the action **102**. Such a scheme works well for the majority of actions because the time it takes to process the request is typically very short. Some types of actions may not have such a short processing time. For such actions, an asynchronous model is more appropriate.

FIG. **11** depicts a flow chart for an asynchronous provider actions according to one embodiment of the present invention. Asynchronous provider actions allow for a provisional response to be sent by the protocol provider before the final response is sent to the script instance. For example, suppose an application script **22** places a call to some location. Preferably, application server **12** does not wait for the call to be answered since it could take an unknown amount of time. The request to place the call is passed to protocol provider **26**, which returns a provisional response.

The provisional response indicates that the provider is processing the request but that it may take some indeterminate amount of time. Once the provisional response is received the script instance **22** continues executing normally. Using the example presented above, when a call is placed the provisional response indicates that the initial call request was successful and that the call is proceeding.

Protocol provider **26** then tries to fulfill the request. When the provider **26** is finished executing the asynchronous action request it constructs an asynchronous event, or callback event, and sends it to the script instance **22**. The receipt of an asynchronous callback event indicates that the action transaction is complete. Asynchronous callbacks are a special type of unsolicited event in application server **12**. They contain specific information that allows the virtual machine to map the event to the appropriate script instance and event handler. MCE **10** retains application state by ensuring that actions may call back their initiating script **22**. Asynchronous callback events preferably eliminate the need for polling systems and help minimize resource utilization.

FIG. **12** depicts a flow chart for a native action according to one embodiment of the present invention. Native actions provide application server **12** a method for extending functionality by allow developers to add custom logic that will execute within the script instance **22**'s virtual process space. Native actions provide a technique for executing operations that should reside within the application **20**, but are better suited to traditional programming paradigms like the C++ language.

A native action is preferably always synchronous and is typically used for building application **20** logic that does not need to maintain state beyond the lifetime of the script instance and does not need to monitor any external network service. Unlike provider actions, native actions actually cause virtual machine **24** to execute the action logic within the context script instance.

FIG. **13** depicts a flow chart for a core action according to one embodiment of the present invention. Core actions are typically called by a script instance **22**, but are handled internally by virtual machine **24**. For example, application server **12** supports application control actions such as calling functions, exiting the current function, and ending the script. Preferably, all of such application control actions are core actions. Typically, a core action is a synchronous action.

FIG. **14** depicts an organizational block diagram of functions and data according to one embodiment of the present invention. FIG. **14** may be used to illustrate scoping, which refers to the accessibility of variables and code segments from within different functional blocks.

Preferably, all scripts **22** within an application are independent and invisible to one another. There is preferably no way to execute code, access variables, or interrogate the elements of one script **22** from another. In this embodiment, communication between scripts **22** must occur through a database, through an external messaging component such as protocol provider, or using a shared object called "SessionData" in a Master/Slave script configuration.

In this embodiment, the configuration settings defined by installer **62** are globally available from anywhere with application **20**, but cannot be changed by the application **20** itself. Instead, using the system control panel **18**, an administrator can modify configuration settings for an application **20**.

Preferably, databases **64** may be accessed from within any script **22** within the database's associated application **20**. Such access permits scripts **22** to communicate with one another, or to share data which will persist even after all script instances have ended.

Preferably, all media resources **66** may be accessed and played through any script **22** within application **20**. Multiple scripts **22** may play the same media resource **66** at the same or overlapping times.

In preferred embodiments, communication between applications **20** must occur through an external service, such as a protocol provider or an external database, or using the "SessionData" object in a Master/Slave configuration.

In this embodiment, scripts **22** contain global variables **144** and functions **142**. Global, or script-level variables **144** and functions **142** may be accessed by any function within the same script **22**, but not by other scripts **22**. Functions **142** comprise the lowest level scope in MCE **10**, and thus preferably have access to all other levels above them. Functions **142** may also contain variables **149**, which can be set or modified by function elements, but not by other functions **142**, even those within the same script **22**. Function-to-function communication should be performed by using script-level variables **144**, or function parameters and return values.

FIG. **15** depicts a state machine diagram of execution of a script instance according to one embodiment of the present invention. When a script instance is in the idle state **162** it is waiting to be started and resides in script pool **19**. Once a triggering event **164** that matches that script type is received, the triggered script **22** is executed by virtual machine **24**. At this point, script **22** becomes a script instance and enters the processing function state. When inside state **166**, events are queued in event queue **168** up until the script instance executes an EndFunction action **161**, placing it in the awaiting events state **163**. Preferably, script instances can handle at most a single event at any given time. Any event destined for

the script that is received while processing of a previous event is in progress will be queued up and handled in the order in which it was received.

As described with reference to FIGS. **10-13**, scripts **22** may call actions of various types. A request for such a call put a script instance in state **165** until the appropriate response is received from the action. Processing and queuing of received events is preferably handled by the core engine **27**'s router/event distributor **302**.

FIG. **16** depicts script instances according to a preferred embodiment of the present invention. The basic building block of an MCE **10** application **20** is an application script **22**. Each script **22** represents a potential thread of execution for application **20**. Scripts **22** begin when the application server **12** receives a triggering event. When this occurs, a new script instance of that script **22** is created and executed.

New script instances are executed within the application server **12**'s virtual machine **24**, and each script instance preferably executes in a separate thread or virtual thread. In FIG. **15**, an application called myApp contains two scripts, A and B. Each time a triggering event is received, MCE **10** places a new instance of script A into virtual machine **24**. Whenever a script instance exits, it is removed from virtual machine **24**. Script processing typically occurs inside functions. While a script may contain many functions, preferably only one of those functions serves as the event handler for the application script's triggering event.

As described referencing above Figures, a triggering event is an unsolicited event whose signature corresponds to a script **22** residing in the script pool **19**. Triggering events are a combination of the type of event and specific event parameters required to start a new instance of an application script type. In a preferred embodiment, a triggering event must be unique across application server **12** and be matched with only one application script **22** for execution by virtual machine **24**.

Preferably, an application executed by virtual machine **24** is a collections of scripts **22**. A script **22** specifies a single triggering event and any number of functions. Functions are collections of actions and loops of actions. Functions, loops, and script structure are further described with reference to later Figures.

In a preferred embodiment, a particular script **22** only has one virtual thread of execution and thus only one function can be running at a time. A call stack is maintained when one function calls another. If a non-triggering event is received while a function is executing, it is placed into a queue until that function has completed and a suitable non-triggering event handler can then be located. An application **20** may contain any number of scripts and all those scripts may be executing in parallel handling different triggering events.

In one embodiment, scripts **22** may be master or slave scripts. Such a scheme allows data to be shared between separate script instances. Slave scripts are in every way the same as master scripts with one important exception, they are not registered with router **302** at install-time. Instead, when the master script starts executing, it must enable the slave script explicitly and may at that time modify the triggering parameters of the slave script. When a triggering event comes in for the slave script, the slave script is given a SessionData object. Such an object is preferably given to all scripts at runtime and contains the connections to any databases the application may have defined, the application name, the name of the application partition in which the current script is running, and a hash table that the script can do with as it pleases. A hash table is a contiguous section of memory with a number of addressable elements in which data can be quickly inserted, deleted and found. A slave script preferably gets a reference to the exact same SessionData instance as the master script which enabled it. In this way, the master and slave scripts may share data back and forth via the shared hash table in real time.

Some applications **20** need many threads to handle many sessions at once. For example, a particular application **20** may wish to place a large number of calls. One script **22** having only one thread of execution will typically not be able to handle a large number of calls in a timely fashion. Executing a slave script for each call represents one solution. In a preferred embodiment, however, slave scripts are only triggered by their own triggering events.

A special action called SendEvent allows applications **20** to generate such triggering events. Preferably, the SendEvent action is actually a direction to the virtual machine **24**. The SendEvent action allows a script to send a triggering or non-triggering event as if it were a provider.

Using the SendEvent action, a script **22** may place a large number of calls. For example, script A sends 500 triggering events of type "NewCall." Script A was designed to interact with another script B, which is registered to handle "NewCall" events as a triggering event. In this example, 500 instances of script B will run to handle the triggering events generated by script A.

Further, a script may employ an action called the "Forward" action. The Forward action terminates the current script and forwards all subsequent messages to the designated script instance.

Referring to FIGS. **15** and **16**, and also to FIG. **3**, there are two significant subcomponents to be found associated with virtual machine **24** in a preferred embodiment. These components are script pool **19** and script scheduler **24**A. When an virtual machine **24** is first constructed by the Application Manager **28** it places all scripts **22** in the application script pool **19** in memory map form. Script pool **19** then immediately makes copies of them and puts them in a separate area where they await execution. The original (master) copies remain in another area and are only used to make additional script copies when necessary.

When a triggering event arises for a script **22** in this application **20**, the script pool **19** gives scheduler **24**A the waiting copy and immediately begins making a new copy from the master. Scheduler **24**A then seeds the script **22** with the data from the triggering event, initializes any global variable values from config, initializes any function variables from the event parameters, and executes the first action.

Scheduler **24**A preferably schedules script instances in the same way a multi-tasking operating system schedules processes. Instead of using timeslices, scheduler **24**A treats each action as an atomic operation. Native actions executed to completion in one cycle of scheduler **24**A. Provider actions simply create an inter-thread message and send it down into the core for handling. Scheduler **24**A preferably does not wait for provider responses. When the provider response is received it is placed on in coming response queue and handled when that script **22**'s turn comes back around. Provider actions which take a long time are broken into three parts instead of the usual two: Action, response, and asynchronous callback (FIG. **11**). Metreos.CallControl.MakeCall is an example of one such action. It sends a response (provisional) to indicate that it is trying the number so the script can go on executing in the interim. When the remote party answers the phone, an asynchronous callback is sent to application **20** to indicate the answer along with all the pertinent data. Application **20** handles this in the same way it does a non-triggering event.

In a preferred embodiment, there is only one scheduler **24**A, part of the virtual machine **24**, for each application **20**. Scheduler **24**A schedules all instances of all scripts **22** currently running for that application **20**. Alternatively, if the were no scheduler, each script would have its own execution engine and run in its own thread. Such an embodiment is not, however, preferred. In situations such as the example above describing 500 calls, such an embodiment would be unwieldy and may violate operating system limitations if each instance actually had its own thread.

Preferably, each scheduler **24**A uses a thread pool to avoid being bogged-down under heavy load. Each scheduler **24**A creates a pool of five threads which is dynamically expandable to a configurable limit. The threads are used to execute actions. Thus the number of threads in the pool represents the number of actions which may the executing simultaneously. In such a scheme, scripts **22** preferably have no direct relationship to threads. A script **22** may be assigned a different thread each time an action in the script **22** is executed. Under heavy load, the thread pool will automatically begin spawning new dynamic threads. These threads are preferably set to decay (or self-destruct) after a configurable period of dormancy. Thus if the system is idle for a while, all the thread pools will contract back to the initial five threads.

A script **22** can handle as many non-triggering events as many times as it wants. It is up to the functions themselves to determine when it is time for the script to end.

FIG. **17** depicts a screenshot from a visual designer **16** according to a preferred embodiment of the present invention. The triggering event used to start the "Hello World" application from the example above is illustrated in this screenshot. Intermediate code produced by visual designer **16** to instantiate the depicted event is listed in Table 6. As shown in line 2 of Table 6, a new script instance will begin when an event of type Metreos.CallControl.IncomingCall is received and contains a parameter named "to" with a value of "joe@host.com". If the event has a different value for the "to" parameter, then a new script instance would not start.

TABLE 6

```
1 <trigger>
2   <triggerEvent>Metreos.CallControl.IncomingCall</triggerEvent>
3    <triggerParam name="to">joe@host.com</triggerParam>
4    <triggerHandler>PrintLogMessage</triggerHandler>
5 </trigger>
```

In this embodiment, multiple script types may trigger on the same event type and even the same event parameters. Preferably, the matching criteria such event parameters must be unique. Such unique parameters are known as the triggering event signature. The triggering event signature must contain at least an event type. Further, triggering event declarations in the intermediate code must always include the name of the function that should be called to handle the triggering event.

FIG. **18** is a partial view of one screen of visual designer **16** according to one embodiment of the present invention. Visual designer **16** offers a drag-and-drop application canvas, and compiles nodes and connecting arrows into XML formatted according to Metreos specifications. The core language of MCE applications derives from eXtensible Markup Language (XML). The visual designer **16** application canvas **202** displays a conceptual and logical diagram of data flow through a telephony application or other application developed for MCE **10**.

Further, most of the elements apparent on the application canvas **202** of visual designer **16** correspond in a one-to-one relationship with XML elements. Visual designer **16** converts a particular visual design for an application **20**, consisting of actions, events and routing options, to the compiled XML version of the same application **20**. An XML version of the "Hello World" program depicted in FIG. **18** is listed in Table 7.

In this embodiment, visual designer **16** stores information that contains all of the necessary data to not only generate the application XML, but also to render the application properly on the screen for development. When the visual designer **16** compiles application **20** from the local source code it generates XML formatted according to a Metreos Application Script XML schema. Other schemas may be defined and used. This XML document can be thought of as the intermediate code used by application server **12** for execution.

TABLE 7

```
1 <?xml version="1.0" encoding="utf-8" ?>
2 <serviceApp name="Hello World"
3    xmlns="http://metreos.com/ServiceApp.xsd"
4    xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance">
5    <variable type="Metreos.Types.String">myGlobalVariable</
     variable>
6
7    <trigger>
8       <triggerEvent>Metreos.CallControl.IncomingCall</
        triggerEvent>
9       <triggerParam name="to">joe@host.com</triggerParam>
10      <triggerHandler>PrintLogMessage</triggerHandler>
11   </trigger>
12
13   <function id="PrintLogMessage">
14      <variable type="string">myLocalVariable</variable>
15
16      <action id="1" type="native">
17            <actionName>Metreos.Native.Log.Write</actionName>
18         <actionParam name="message">Hello World!</actionParam>
19         <actionParam name="logLevel">Info</actionParam>
20         <nextAction returnValue="success">2</nextAction>
21         <nextAction returnValue="default">2</nextAction>
22      </action>
23
24      <action id="2">
25         <actionName>Metreos.ApplicationControl.Exit</
           actionName>
26      </action>
27   </function>
28 </serviceApp>
```

Such an XML application storage naturally retains the wide array of benefits provided by XML. Applications may be easily stored on any modern platform, transported across virtually any network infrastructure, and parsed due to a well-defined schema. XML technology may require, however, significant overhead, which may waste resources or increase the potential for error. Preferably, MCE **10** addresses such issues through the use of an application assembler **28** (FIG. **2**), which converts bulky XML into streamlined object code, while checking for correctness and rejecting malformed applications **20**.

Like many programming languages, MCE **10** allows developers to group application logic into functions. In a preferred embodiment, visual designer **16** allows application developers to utilize two types of functions: event handling and standalone. Table 8 shows a listing of how a standard, standalone function declaration is represented in the intermediate XML code generated by visual designer **16**.

TABLE 8

```
1    <function id="StandaloneFunction">
2        <!-- Function Body Removed -->
3    </function>
```

Event handling functions are only executed in response to an event that is received by the script instance. Table 9 shows a listing of the declaration of a function that will handle the Metreos.Providers.Http.GotRequest event.

The presence of the <eventHandler> tag (line 2) indicates to virtual machine **24** that the function should start when an HTTP GotRequest event is received by the script instance. It is important to note that other GotRequest events may be received by the application server **12** and unless they are specifically destined for the script instance they will be treated as potential triggering events. In other words, event handling functions are specifically for handling unsolicited events for currently executing script instances.

TABLE 9

```
1 <function id="HandleHttpRequest">
2 <eventHandler>Metreos.Providers.Http.GotRequest</eventHandler>
3   <!-- Function Body Removed -->
4 </function>
```

In a preferred embodiment, a function also contains a signature that must be present in the input parameters passed to the function when it is started. Function parameters behave the same when used in both standalone and event handling functions. To indicate that a function takes an input parameter, a <variable> element must be added and that element must include an initWith parameter as shown in the code listing of Table 10.

TABLE 10

```
1    <function id="FunctionWithInputParameters">
2      <variable type="Metreos.Types.String"
3          initWith="someParameter">variableName</variable>
4      <!-- Function Body Removed -->
5    </function>
```

Preferably, a function may have as many input parameters as the application developer chooses to add. If the function is marked as an event handler and also includes input parameters, then the <eventParam> elements must be included to indicate the matching criteria for the event handler as shown in Table 11. The function name, and optionally, its parameters and type of event that it may handle, constitute the function signature.

TABLE 11

```
1    <function id="HttpEventHandlerA">
2      <eventHandler>Metreos.Providers.Http.GotRequest</
       eventHandler>
3      <eventParam name="url">/some/url</eventParam>
4      <variable type="Metreos.Types.String"
5          initWith="url">requestUrl</variable>
6      <!-- Function Body Removed -->
7    </function>
8
9    <function id="HttpEventHandlerB">
10     <eventHandler>Metreos.Providers.Http.GotRequest</
       eventHandler>
11     <eventParam name="url">/another/url</eventParam>
12     <variable type="Metreos.Types.String"
13         initWith="url">requestUrl</variable>
```

TABLE 11-continued

```
14     <!-- Function Body Removed -->
15   </function>
```

In a preferred embodiment, function signatures, much like the triggering event signature, must be unique. The primary difference between the two is their scoping. Triggering event signatures must be unique across the entire system. In other words each application script type must have a different triggering event signature. In contrast, function signatures must be unique within the application script itself.

For example, given the event handling functions shown in Table 11 it is apparent that both functions handle the HTTP GotRequest event. Furthermore, both functions declare an event parameter that must match against the url field in the incoming event. The first function, HttpEventHandlerA will be executed when a GotRequest event is received that was destined for "/some/url". If the request was sent to "/another/url" then the second event handling function, HttpEventHandlerB, will be executed. If neither function matches then the event will not be handled and will, in this example, be ignored. Application server **12** will pick the best matching event handler for the specified parameters.

In a preferred embodiment, a function is displayed in visual designer **16** as a web of interconnected action icons such as, for example, those depicted in FIG. **19**. Each of the connections is labeled. Those labels indicate the path that execution will follow depending on the result of the prior action. All actions must return a result. That result is preferably a free-form string. If there is no path defined for a particular value of result, the "default" path is taken. Within the context of a loop, an action may point to the edge of the loop bounding box indicating that execution should return to the first action in the loop (i.e. "continue") or the next action after the loop if the loop count has been reached. Alternately, an action within a loop may point to an action outside the loop to indicate that execution should leave the loop unconditionally (i.e. "break").

One or more actions may reside inside a loop. A loop may be designated in visual designer **16** as a dashed rectangle around the set of actions. In the generated XML, loops have their own section within a function declaration. A loop has only one property, the loopCount. There are three different types of loop counts.

A loop count of Literal (int) type is eventuated in a standard for-loop. The index is an integer, referenced as "loopIndex", which starts at zero and increment until loop count minus one.

In this embodiment, the other two loop counts are types Enumerable (IEnumerator) and Dictionary (IDictionaryEnumerator). Another preferred embodiment uses the Java equivalent. These loop count types can only be derived from variable or C# or Java loop count declarations. It is preferably not possible to specify an Enumerable or Dictionary loop count with a literal value. Preferably, the loop count for loop type Enumerabe must resolve to an object which implements System.Collections.Ienumerable, or the Java equivalent. This type of object is preferably a one-dimensional collection over which loop may iterate. The loop index, referenced as "loopEnum", is initialized with the enumerator for the collection and positioned at the first item. The current item in the collection is referenced as "loopEnum.Current". The loop continues until the enumerator reaches the end of the collection.

The Dictionary type loop count works the same as enumerable except that it works with name-value collections, like

Hashtable. The Dictinary loop count is referenced as "loopDictEnum" and the current values are referenced as "loopDictEnum.Key" and "loopDictEnum.Value".

Using such a loop count scheme, it is possible to loop for a constant amount of time or iterate over any collection of unknown size. The names mentioned above for referencing the current index can be used inside of any C# or Java code segment (i.e. Native action, UserCode action, or C# action parameter).

Only one function is designated to start when a script **22** begins. From there, it may call other functions. When the main function is complete, the script may exit or it may wait for non-triggering events. Any number of functions can be defined to handle any number of non-triggering events.

For example, application **20** called MyApp contains one script **22**, "HandleIncomingCall". That script **22** has a function "OnIncomingCall" which is set to execute when the triggering event Metreos.CallControl.IncomingCall is received. The function executes and then exits without terminating the script. The script **22** has another function called "OnHangup" which is set to begin executing when the non-triggering event Metreos.CallControl.Hangup is received. When that non-triggering event comes in, the OnHangup function executes then elects to terminate the script **22**. At that point, the virtual machine **24** removes the script from the scheduler's execution queue.

Variables allow application developers to store and manipulate data within their application scripts. Variables may either be initialized with a default value or initialized using incoming event parameters. Furthermore, variables may be globally or locally scoped. A global variable is visible and useable in all functions, whereas a local variable is visible and usable only within the function where it is defined.

TABLE 12

```
1  <?xml version="1.0" encoding="utf-8" ?>
2  <serviceApp name="Conference Application"
3     xmlns="http://metreos.com/ServiceApp.xsd"
4     xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance">
5     <variable type="Metreos.Types.String">myGlobalVariable</
      variable>
6
7     <!-- Trigger Removed -->
8
9     <function id="PrintLogMessage">
10       <variable type="string">myLocalVariable</variable>
11       <!-- Function Body Removed -->
12    </function>
13 </serviceApp>
```

The code listing in Table 12 shows how global and local variables are represented in a preferred embodiment MCE **10**'s application script XML intermediate language. A global variable declaration appears in line 5. Notice that line 5 is within the script listing but is not within the function declaration beginning at line 9. The function declaration at line 10 is a local variable within the function declared at line 9.

Global and local variables act differently when they contain initWith attributes. When global variables are initialized using initWith, application server **12** attempts to retrieve configuration values from the configuration database to store in the global variable. For an example, see the global variable declaration shown in the code listing of Table 13.

When a new script instance of a script type containing the code in the preferred scheme of Table 13 starts execution, the application server **12** will attempt to initialize myGlobalVariable with the value of the SomeConfigEntry configuration parameter (line 3). If it is unable to do so, the script instance will not start. If Table 13 had instead declared a local variable within a function, the application server **12** would attempt to initialize it with a value from the incoming event message. The message would be searched for a parameter named SomeConfigEntry, and if found, its value would be placed into myGlobalVariable.

TABLE 13

```
1 <serviceApp>
2    <variable type="Metreos.Types.String"
3          initWith="SomeConfigEntry">myGlobalVariable</variable>
4 </serviceApp>
```

Preferably, a large part of most application scripts is the conditional logic constructed by linking together actions. Actions were previously discussed in context of the application server **12**'s execution model. Table 14 shows how a simple action map would be represented in the application script's intermediate XML code. In a preferred embodiment, each action is comprised of two mandatory elements: actionName and nextAction. Each action may also define zero or more actionParam elements.

In this embodiment, the flow of the application script is defined by how the actions link to one another, as represented by the nextAction elements (lines 6 and 7, line 14). Each nextAction element contains a returnValue attribute which indicates which path to take, based on the result of the action.

TABLE 14

```
1  <function id="PrintLogMessage">
2     <action id="1" type="native">
3        <actionName>Metreos.Native.Log.Write</actionName>
4        <actionParam name="message">Hello World!</actionParam>
5        <actionParam name="logLevel">Info</actionParam>
6        <nextAction returnValue="success">2</nextAction>
7        <nextAction returnValue="default">3</nextAction>
8     </action>
9
10    <action id="2" type="native">
11       <actionName> Metreos.Native.Log.Write </actionName>
12       <actionParam name="message">Hello World,
         Again!</actionParam>
13       <actionParam name="logLevel">Error</actionParam>
14       <nextAction returnValue="default">3</nextAction>
15    <action>
16
17    <action id="3">
18       <actionName>Metreos.ApplicationControl.Exit</actionName>
19    </action>
20 </function>
```

FIG. **19** depicts a graphical user interface screenshot for a visual designer **16** according to one embodiment of the present invention. The various portions of graphical user interface **200** will be further described with reference to FIG. **20** together with FIG. **19**.

FIG. **20** depicts a block diagram of components of the graphical user interface depicted in FIG. **19**. In this preferred embodiment, graphical interface **200** of visual designer **16** has application canvas **202**. Elements of the telephony application **20** appear as nodes **207** in a web-like diagram depicted on application canvas **202**. Routing arrows **208** indicating the flow of program execution based on defined conditions. Nodes **207** represent either actions called by application **20** to achieve a desired affect, or programmatic control structures. Nodes **207** are dragged from toolbar **204** ("toolbar", "toolbox", "project toolbox") onto application canvas **202**.

The user may create diagrams on application canvas **202** using application elements from toolbox **204** such as, for

example, actions, control structures, and variables. Such elements are linked to form the design of an application **20**. A particular diagram for an application **20** may become much larger than the user's screen. Application canvas **202** may be panned up and down or left and right using scrollbars to accommodate such large views.

Tabs **209** are provided to further accommodate viewing a large application, and to separate application diagrams logically or structurally. Tabs **209** in FIG. **19** operate to change the view on application canvas **202**. Some exemplar views are depicted as separate blocks **202**A, **202**B, and **202**C in FIG. **20**.

In a preferred embodiment, script view **202**A shows the entire diagram of a script. Function 1 view **202**B shows a diagram of a particular function which may be entered by the user or pulled from a library, another program, or other sources. View **202***a* is preferably a view of the first (triggering event) function in application **20**. Function n view **202**C depicts the possibility of further function views, which are preferably accessible in sequential order according to their appearance in the application. Other views are possible. Examples of such other views are data views and screen views. Other viewing schemes are further described with reference to later Figures.

Project explorer **201** presents a tree view of application **20** components which may be navigated through interaction with explorer **201**. Preferably, project explorer **201** lists all chief components of the currently loaded application **20**, grouped by category. Components may include scripts **22**, installers **62**, databases **64**, and media resources **66**. Project explorer **201** acts as the main navigation system for visual designer **16**, permitting developers to switch between each piece of a large application **20**.

In this embodiment, application components or elements reside in toolbox **204**. A user adds an element to an application by clicking on the appropriate category heading **210** listed in toolbox **204** and then dragging and dropping the desired element onto application canvas **202**. In a preferred embodiment, third-party components may be added to toolbox **204** by developing new protocol providers **26**.

Overview window **203** in this embodiment displays a small representation of the current application canvas **202**. A rectangle **211** overlaid on overview window **203** indicates the area of the canvas **202** currently visible onscreen. Users may click and drag a new rectangle **211** to change the viewing area of application canvas **202**. Users may also drag rectangle **211** or move it with arrow keys to navigate canvas **202**.

Variables tray **212** displays variables that are local to the current function or script displayed on canvas **202**. Users may change various property settings associated with an element using properties window **205**. A user may focus property window **205** onto a particular element by clicking on a specific instance of the element on application canvas **202**, or by clicking on the original element item in toolbox **204**. Different elements types of elements will present different properties for modification. Such properties may be, for example, initialization values or return values. Property window **205** permits modification of properties for actions, events, variables, scripts, and projects.

When a user compiles an application **20** for eventual installation to application server **12**, the compiler may generate information, warning, or error messages. Such messages preferably appear in output window **206**. Preferably, a user can click on a message to navigate to an associated element.

Remote console window **213** may be activated to show the console view (interface screen) remotely for a particular MCE **10** system to which visual designer **26** may be connected. Such a view may be useful for debugging, operations, and maintenance.

Still referring to a preferred embodiment of visual designer **16**, call stack docking window **214** provides a user with detailed information on protocol stack or call stack of calls within application **20**. Such information may be useful for debugging. Breakpoints docking window **215** allows a user to manage breakpoints within an application **20** for debugging purposes. Watch docking window **216** shows debugging values of variables or elements on which a user has set a watch. Debugging within visual designer **16** is further described with reference to later Figures.

FIG. **21** depicts a structural block diagram of a visual designer **16** according to a preferred embodiment of the present invention. In this embodiment, visual designer **16** comprises an application framework **210** and a drawing framework **212**.

Application framework **210** comprises a main module **214** including a menu manager and dialog manager for visual designer **16**. Application framework **210** also has a number of satellite window managers **216** for managing the various windows above with reference to FIG. **19**.

Utility managers **218** manage various housekeeping aspects of visual designer **16**, including a Web Services Description Language (WSDL) Manager. Packages manager **220** manages the various packages that may be installed with visual designer **16**, including third party toolboxes and packages. Event router **222** generates routes for various events associated with script **22** functions. Further, applications framework **210** includes various resources **224** employed by visual designer **16**.

Drawing framework **212** includes managers **226**. Managers **226** include a project manager for encapsulating projects within visual designer **16**, a script manager, and a canvas tab manager. Further included are various serializers such as, for example, an XML serializer and a database serializer. Such serializers are known in the art, and are operational to convert the drawing layouts and other objects in visual designer **16** to code.

Drawing framework **212** further includes canvases modules **228** for implementing the various visual interfaces to visual designer **16**. Also included in drawing framework **212** are various node modules **230** to implement nodes which make up the various applications.

Dialogs module **232** manages various dialogs which may be presented to the user. Debugger module **234** includes various submodules for implementing interfaces to MCE **10** and to visual designer **16** users and modules to provide debugging functionality. Debugging will be further described with reference to FIG. **25**.

Further, visual designer **16** includes various other modules **236** such as custom editors which may be launched by visual designer **16** to allow editing of third party components or custom views. A custom properties module allows developers to add and manage custom properties to the various objects included in an application.

FIG. **22** depicts a flow diagram of a typical usage scenario of a visual designer **16** according to one embodiment of the present invention. Starting with an idea for a new application in step **2201**, a user proceeds to define business logic for the application in step **2202**. Defining the business logic may include defining Native Actions in step **2215**, which includes creating any custom "tools" required by the application **20** and installing a package for each of such tools using a designer's "Add/Remove Packages" menu. Further, a user may define provider actions in step **2216**. If necessary, this step

defines and installs any custom modules with relationships between an application **20** and the outside world.

In step **2203**, the user selects a new project from within visual designer **16**. Preferably, visual designer **16** uses a project metaphor to aid developers in organizing applications and applications and application components into a logical system. Creating a new project within the visual designer **16** requires creating a folder on the developer's system or a shared network drive, usually with the same name as the application **20**. Within this folder, visual designer **16** stores all the application components. The folder contains files which represent all the scripts **22** used in application **20**, the files with configuration and installation data for application **20**, and the files containing SQL code for databases required by application **20**. After creation of the project, any installed provider and native actions are displayed in Designer's Toolbox. The user may also specify a "triggering event" at this step.

In step **2204**, the user constructs a new application script **22**. This step further involves dragging and dropping any global variables onto the canvas. In step **2205**, the user defines the functionality of the application, which is typically a VoIP application. Other types of applications may also be built with visual designer **16**, such as, for example, PSTN telephony applications. Defining functions includes, in step **2206**, drag and drop actions and variables from Toolbox onto canvas **202**. In step **2207**, the user sets properties of each element using the property window **205**. In step **2208**, the user defines logic flow among the various functional elements. Step **2208** typically involves dragging arrows between elements, visually setting arrows'branch conditions, and dragging and dropping other logical constructs from the Toolbox, such as loops and function calls.

Steps **2206**, **2207**, and **2208** are iterated for functional elements until the function is complete (step **2209**). Additional functions are added by repeating the process until the script is complete (step **2210**). Further scripts are added until the application **20** is complete (step **2211**).

A completed application is built and tested according to step **2212**. In step **2218**, to compile the application, the user preferably selects build from the Designer menu, or hits a "build" button. In step **2219**, users correct any resulting errors. Deploying the application in step **2220** involves Select "Deploy" from the Designer menu. The application is installed to Application Server **12** by a process described further below. User's may employ debugging capabilities of application server **12** and visual designer **16** to test the application in step **2221**.

FIG. **23** depicts a flow chart of using a multiple view capability to build scripts **22** according to one embodiment of the present invention. Typically, this capability is used to construct an IP phone application **20** using multiple interchangeable views of the application scripts **22**.

In step **2302**, in the traditional function view, building blocks are actions, which are dragged from the Toolbox and dropped onto a function canvas as described with reference to FIG. **19** and further with reference to FIG. **22**. Logic flow is indicated by dragging arrows between action nodes, and visually setting a branch condition for each such arrow. Transfer of control is specified by dragging from the toolbox to the canvas logical constructs, such as, for example, Call Function, Loop, End Function, Label, Compare, and Switch.

In step **2303**, the user may switch to Phone View to see the application as it appears on an IP phone display. User drags graphical building blocks from the toolbox onto the phone view, such as Menu, Softkey, Image, Directory, Button, and Text. Handler functions may be defined for softkeys. The user may then switch to Function View to define the handlers. User interface objects such as images may be visually repositioned and resized. Further, Images, directory text, menu text, button text, etc., may be bound to database content.

In step **2304**, the user may switch to IVR (interaction voice response) view. This view allows the user to build an application script by visually specifying call flow through a tree of IVR prompts and menus. Nodes in the tree may be linked to media prompts.

In step **2305**, the user may switch to a Site Map View to see and build the mapping between soft keys and application "pages" in VoIP application or other application involving interactive pages.

FIG. **24** depicts a flow chart of using a web services integration capability according to one embodiment of the present invention. Such a capability is devised to help users incorporate or integrate functionality defined in an existing web service as actions in a visual designer **16** application. Such integrated services may include, for example, the use of a "Do Not Call" registry and the use of a location-based content servers. The user launches a web services wizard in step **2401** to begin integrating a particular web service.

In step **2402**, visual designer **16** presents a dialog in which user specifies a URL or path to a remote or local web service description file. If the web service is found, user presses Next to continue.

In step **2403**, visual designer **16** presents a dialog in which each method of the located web service is displayed. The user verifies that the methods are as expected, enters a name to describe the web service on the local machined, and presses Next to continue.

In step **2404**, visual designer **16** interprets the web service description file, creating a local proxy method for each method in the web service. Visual designer **16** also presents a dialog displaying each method proxied, and solicits the name of a new or existing Designer Toolbox tab under which to insert tools for each such method.

In step **2405**, visual designer **16** Designer installs the web service as a Designer Package, and inserts a tool for each proxied method onto the selected Toolbox tab. The user presses Finish to commit changes, or Back to undo changes. Such navigation preferably is available between all steps presented by visual designer **16** as part of the web services wizard.

In step **2406**, the user may now use the web services tools by dragging and dropping onto application canvas **202**, connecting, and setting properties as described above.

FIG. **25** depicts a flow chart for a process of installing an application on application server **12** according to a preferred embodiment of the present invention. The installation process is mostly completed by assembler **28**. Assembler **28** is responsible for unpackaging applications, compiling them, and creating application runtime AppDomains **21** (FIG. **3**). Assembler/application manager **28** also plays a minor role in script debugging by routing the debug commands to the appropriate application.

Applications **20** are usually deployed from visual designer **16**. The usual sequence of events is that a developer uses visual designer **16** to create an application **20**, packages it, and deploy it to application server **12**. When visual designer **16** packages an application **20**, it invokes the same static script compiler the Application Server **12** uses just to ensure that there are no errors in the application. Then it locates any custom actions and/or types that the user has linked into this application **20** and zips it all up into one file using the name of the application as the filename and a ".mca" extension (step **2502**).

It then connects to Application Server **12**, preferably via an application deployment Secure FTP interface, and transfers the archive to the destination MCE **10**. (Step **2503**). Assembler **28** has a deploy watcher which watches the deployment directory for new files. It is also possible to install a packaged application **20** via the system control panel **18** management website or by direct connection using a standard SFTP client. Use of visual designer **16** is preferred.

Assembler **28** begins by extracting the archive into a temporary directory. Next it checks to see if this application **20** is already installed. If it is, then the existing application **20** is uninstalled and its data prepared for upgrading. Otherwise, it inserts any configuration items that application **20** has defined into the configuration database **310** (step **2504**). Such items may then be viewed and modified from the system control panel **18** management website. Next, assembler **28** creates any databases the app has defined (step **2505**). Then assembler **28** sends out copies of any media files included in the archive to all configured media servers via SFTP (step **2506**).

Assembler **28** next compiles the scripts into memory-maps and creates a new AppDomain **21** and virtual machine/runtime environment **24**. Then the default application partitions are created in the configuration database with the dev-time triggering criteria (step **2507**). Assembler **28** finishes by feeding the scripts to script pool **19**. The virtual machine **24** then registers all the scripts with the Router and the script is ready for execution on application server **12**.

Similarly, assembler/application manager **28** responds to requests from the system control panel **18** management website, via the management interface, to uninstall applications. It does so by first sending the virtual machine **24** in question a message telling it to uninstall. Virtual machine **24** responds by notifying router **302** that it is about to be uninstalled and unloading any running scripts. Next, Application Manager **28** deletes the respective AppDomain **21**.

Referring in more detail to step **2507** in FIG. **25**, script compilation is the process of converting an XML representation of a script **20** into a memory-map object. As described above, a script **20** is a collection of functions which are each a collection of actions. In a preferred embodiment, there are three types of actions and the compiler must handle each type differently as they are encountered: provider actions, native actions, and UserCode actions.

Provider actions are actions in which the XML specifies in plain text strings the name of the action and all the parameters as name-value pairs. To compile a provider action, the assembler **28** has to these strings into a class. The virtual machine **24** will see this at runtime and generate an inter-thread message to send to the designated provider.

A native action is a class which conforms to a well-defined interface which contains an Execute( ) method which will be called directly by the virtual machine **24** at runtime. The parameters and return values of a native action are defined by decorated properties with "set" and "get" accessors as appropriate. Such properties are preferably implemented as a formal .NET or Java construct. MCE **10** includes many native actions to assist developers. Additionally, developers may include custom-built actions by creating a reference to them in visual designer **16**. Visual designer **16** then includes these assemblies in the application package. When the assembler sees this, it places them in a "NativeActions" directory under the application install directory.

The compiler locates the assembly containing the action in question using reflection (preferably implemented with .NET or Java), instantiates the action, and stores a reference to it as the entry for this action in the memory-map.

UserCode actions similar to native actions concerning how virtual machine **24** treats them, but instead of the developer providing a pre-compiled assembly with the action code in it, they supply the code itself in un-compiled form as a single function. So assembler **28** creates an in-memory code block (CodeDom) and appends these snippets of code as abstract classes with a single static Execute( ) method as it finds them. When all the actions have been processed, assembler **28** compiler invokes a C# or Java compiler to compile this block of accumulated code. Assembler **28** then goes back to each of the UserCode actions and searches the generated assembly for the compiled functions. As it finds them, it adds method references (MethodInfo) as that respective action's entry in the memory-map.

When the virtual machine **24** encounters UserCode actions, it preferably treats them differently than provider actions. Since the UserCode action is preferably comprised of only a single function, it does not have properties. Thus, the parameters of the Execute( ) method serve as the parameters for the action. The name of the parameter must be a variable name and the type must be correct for that variable. Then the virtual machine **24** passes that variable value into the function. In a preferred embodiment, a UserCode action can only take variables as parameters, there is no way to pass in literals or C# or Java expressions. There are, however, a few special parameters UserCode actions can include to get runtime information or services: "LogWriter log", "int loopIndex", "IEnumerator loopEnum", "IDictionaryEnumerator loopDictEnum", and "SessionData sessionData". Preferably, only one of the loop parameters may be used at a time and it must be the correct one for the type of loop this action is contained in. The other special parameters are preferably always available.

With continuing reference to the assembly process with respect to variables, variable types must be declared. A type, within the context of an MCE **10** application **20**, is a class which conforms to a well-defined interface. The class must be capable of being assigned a string, resolving to a string, and being reset. Further, the type may include and publish any number of proprietary methods which are useful for this type.

Like native actions, most common types are included with MCE **10**. These types (string, bool, int, etc) preferably behave like native .NET or Java types. These types are preferably implement a different interface which, when encountered, signals the virtual machine **24** to extract their underlying type and use that instead of the artificial wrapper. Developer-built types are referenced in visual designer **16** and packaged in the same way native actions are. Assembler **28** puts developer-built types in a "NativeTypes" directory under the application install directory. When creating a variable of that type, the class for the type is instantiated and a reference is stored in the variable information object which is stored in a "variables" section in the memory-map.

Referring now to assembler **28**'s handling of action parameters, action parameters can be one of three types: literal, variable, and a code expression (preferably either C# or Java).

If a literal value is specified for an action parameter, virtual machine **24** will pass it as a string if the action is a Provider action. It is the provider **26**'s responsibility to cast or parse its parameters as necessary. Otherwise virtual machine **24** will attempt to cast or parse is to the required type for a Native action.

A variable action parameter merely identifies the variable who's value should be passed in. The virtual machine **24** will search for the variable by looking first at the function variables, then at the global variables. When it finds the desig-

nated variable, it passes the value as it is into the action regardless of whether it is a Provider, Native, or UserCode action.

A C# or Java action parameter is a snippet of code, similar to a UserCode action, except that it can only be a single statement which must resolve to an object. When assembler **28** encounters this, it stubs out a class and a function which initializes all the local and global variables (in addition to the special parameters mentioned for UserCode actions), so they are available to the snippet, and places the snippet just after the "return" statement so it will be evaluated and return with the function. Then, just like a UserCode action, a method reference (MethodInfo) is saved for that action parameter so it can be evaluated later at runtime.

FIG. **26** depicts a flow chart of a debugging process according to one embodiment of the present invention. Such a process may be employed when a user wishes to diagnose a visual designer **16** project by visually tracing execution of an application script **20**. In step **2602**, the user may set one or more breakpoints from either the main menu, or from a context menu on a selected function canvas action node. Enabled breakpoints appear as a red circle next to the action node. Breakpoints may be disabled or cleared in a similar manner.

In step **2603**, the user begins debugging of the application script **20** by selecting Start Debugging from a menu, or by pressing the F5 key. The application **20** begins execution in debug mode.

In step **2604**, when an action is reached on which a breakpoint has been set and enabled, execution pauses before execution of the action, and a halo is drawn around the action on canvas **202**. The state of global variables, and variables local to the current function, are displayed in the Watch window **216**. the user selects Continue or Step from a menu to resume execution.

In step **2605**, the user can single step from action to action, starting either at the beginning of the application, or at a current break action. Stepping is selected via menu or function key. When stepping, execution pauses at each node visited, and a break halo is drawn around the node on canvas **202**. If the action is Call Function, selecting Step Into will single step into the body of the called function. If the user selects Step Over, the function executes and execution pauses at the next action after the function return point.

To stop debugging in step **2606**, the user selects Stop Debugging from a menu or function key, and the application exits. The debugging process described herein is merely exemplary and other scenarios and control means may be used.

In a preferred embodiment, application server implements the described debugging capability as follows. Upon receipt of the command to start debugging, visual designer **16** establishes communication to debug module **306** and OAM module **29** on the target application server **12** (FIG. **3**).

A debugging session begins when the visual designer **16**, acting as a client, sends a StartDebugging command to OAM module **29**, acting as a server. When virtual machine **24** gets this message, it creates a new type runtime data structure to handle debug-related state information and associates it with the specified script **20** (not an instance yet). The next time a script **20** of that type starts (becomes a script instance), virtual machine **24** will link the debug information object to it and that script instance will then be in debug mode.

Before debug mode occurs, visual designer **16** user preferably will set some breakpoints. The user does this by simply right-clicking an action in a script and selecting "Set Breakpoint". Visual designer **16** translates such an request into a command and an action ID and sends it to the application server where that information is stored in the debug information object. Application manager **28** preferably routes debug messages.

Table 16 contains a list of possible debugging commands in a preferred embodiment. Breakpoints may be set and cleared at any time. A developer can set all desired breakpoints at once or only set one and once that is reached, set the next one. When virtual machine **24** sees that an action is marked as a breakpoint, it does not execute the action. Instead, it sends a HitBreakpoint command to the connected client. The client may then elect to do any number of things. The client can send a Run command if they wish for execution to continue to the next breakpoint or script end.

TABLE 15

Client Debugging Commands:
1. StartDebugging
2. StopDebugging
3. SetBreakpoint
4. GetBreakpoints
5. ClearBreakpoint
6. Run
7. StepOver
8. StepInto
9. Break
10. UpdateValue
Server Debugging Commands:
1. StopDebugging
2. HitBreakpoint

The client may send a StepInto or StepOver to execute only one action. The difference between StepOver and StepInto is only made if the action is a CallFunction. StepOver will execute the called function and break on the next action in the current function. StepInto will step into the function an break on the first action. Regardless, of which was chosen, a HitBreakpoint command will be sent to the client along with the state of all the variables and SessionData to indicate that execution has stopped again.

At any time in script execution, the client may issue a Break command. The Break command will cause virtual machine **24** to halt execution at whatever action it is on, and send all the state information, variable values and SessionData information to the client in a HitBreakpoint message. Virtual machine **24** will then wait for further instruction.

While script **20** is paused on an action due to any debug command, the client may elect to send an UpdateValue command. This will cause the value of the specified variable to change to the specified value in that script instance in real time. When script **20** finishes executing, the server will send a StopDebugging command to the client to indicate this. If the client no longer wishes to debug script **20**, it may issue a StopDebugging command to the server which will clear any breakpoints and put script **20** back in a running state.

FIG. **27** depicts a block diagram of a media server **14** according to a preferred embodiment of the present invention. Preferably, a media server **14** is used having compatibility with the Intel® Host Media Processing (HMP) software standard. Protocol adapters **2701** handle require for connection and media manipulation services over a variety of protocols, such as, for example, MGCP (Media Gateway Control Protocol), XML, VoiceXML, SIP, Megaco, and JTAPI. Protocol adapters **2701** are preferably extensible to support further protocols.

Command map **2702** is the source of requests to and local sink responses from the remainder of media server **14**'s architecture. Command map **2702** and protocol adapters **2701**

translate media requests to the media server **14**'s API. Client manager **2703** and server manager **2705** manage media requests through queues **2704**. Such a scheme allows a protocol adapter **2701** to leave a request on the server queue **2704** and not be required to wait for a response.

Session manager/conference manager **2706** setup and manage sessions. The session manager observes connection threads, and performs management tasks such as identifying connections which may be in limbo, terminating them to make their connection thread available. The conference manager associates connections with conferences and is responsible for accessing HMP resources to start and terminate conferences, adjust conference parameters, and add and remove connections to and from conferences.

Session pool **2707** and service thread pool **2708** make available a number of threads of execution, each of which may be responsible for handling media firmware service requests and results through media manager **2710** and event manager **2709**. Media firmware **2711** interacts with media manager **2710** according to the HMP protocol and provides access to various media resources.

Although the present invention has been described in detail, it will be apparent to those skilled in the art that many embodiments taking a variety of specific forms and reflecting changes, substitutions and alterations can be made without departing from the spirit and scope of the invention. The described embodiments illustrate the scope of the claims but do not restrict the scope of the claims.

The invention claimed is:

1. A method of creating a telephony application using a graphical user interface, the method comprising:

displaying a visual designer having the graphical user interface, wherein the visual designer is displayed on a display screen using instructions executed by a computer processor, wherein the computer processor is coupled to a user input device, wherein the visual designer provides user interface controls for creating the telephony application;

displaying a toolbox area in a first area on the display screen, wherein the toolbox area includes elements;

displaying an application canvas area in a second area on the display screen;

displaying an overview window in a third area on the display screen, the overview window displaying a smaller current view of the application canvas area;

accepting a signal from the user input device to select a first AnswerCall element in the toolbox, wherein the first AnswerCall element has associated functionality for answering a call;

accepting a signal from the user input device to move a copy of the first AnswerCall element into the application canvas area;

accepting a signal from the user input device to select a second AnswerCall element in the toolbox, wherein the second AnswerCall element has associated functionality for answering a call;

accepting a signal from the user input device to move a copy of the second AnswerCall element into the application canvas area;

accepting a signal from the user input device to select a SetMedia element in the toolbox, wherein the SetMedia element has associated functionality for setting parameters in a media device;

accepting a signal from the user input device to move a copy of the SetMedia element into the application canvas area;

accepting a signal from the user input device to make a first connection from an output of the first AnswerCall element in the application canvas area to the SetMedia element in the application canvas area, wherein the first connection includes an arrow at the SetMedia element in the application canvas area;

accepting a signal from the user input device to make a second connection from an output of the first AnswerCall element in the application canvas area to the second AnswerCall element in the application canvas area, wherein the second connection includes an arrow at the second AnswerCall element in the application canvas area;

receiving a signal from the user input device to compile the application; and

generating executable statements that include script commands associated with the first and second AnswerCall elements and the SetMedia element to generate at least a portion of the functionality of the telephony application.

2. The method of claim **1**, further comprising displaying a plurality of tabs in the application canvas area for the associated functionality for answering a call when the first or the second AnswerCall element is selected.

3. The method of claim **2**, further comprising displaying event handler actions in a text box area in the application canvas area for the associated functionality for answering the call when the first or the second AnswerCall element is selected.

4. The method of claim **2**, further comprising accepting a signal from a user input device to select one of the plurality of tabs for display of the associated functionality related to the selected AnswerCall element.

5. The method of claim **2**, wherein the plurality of tabs comprises call complete and call hang-up functionality related to the selected AnswerCall element.

6. The method of claim **1**, further comprising accepting a signal from the user input device to select a SendUserInput element, wherein the SendUserInput element has associated functionality for defining user inputs when answering a call.

7. The method of claim **6**, wherein the defined user inputs include a dual-tone multi-frequency (DTMF) signal.

8. The method of claim **6**, further comprising accepting a signal from the user input device to make a third connection from an output of the SetMedia element in the application canvas area to the SendUserInput element in the application canvas area, wherein the third connection includes an arrow at the SendUserInput element in the application canvas area.

9. The method of claim **6**, further comprising accepting a signal from the user input device to select an EndFunction element.

10. The method of claim **9**, further comprising accepting a signal from the user input device to make a fourth connection from an output of the SendUserInput element in the application canvas area to the EndFunction element in the application canvas area, wherein the fourth connection includes an arrow at the EndFunction element in the application canvas area.

11. An apparatus for creating a telephony application using a graphical user interface, the apparatus comprising:

a computer processor; and

logic encoded in one or more tangible media for execution by the computer processor, and when executed, operable to perform the following steps:

display a visual designer having graphical user interface, wherein the visual designer is displayed on a display screen using instructions executed by the computer processor, wherein the computer processor is coupled

to a user input device, wherein the visual designer provides user interface controls for creating the telephony application;

display a toolbox area in a first area on the display screen, wherein the toolbox area includes elements;

display an application canvas area in a second area on the display screen;

display an overview window in a third area on the display screen, the overview window displaying a smaller current view of the application canvas area;

accept a signal from the user input device to select a first AnswerCall element in the toolbox, wherein the first AnswerCall element has associated functionality for answering a call;

accept a signal from the user input device to move a copy of the first AnswerCall element into the application canvas area;

accept a signal from the user input device to select a second AnswerCall element in the toolbox, wherein the second AnswerCall element has associated functionality for answering a call;

accept a signal from the user input device to move a copy of the second AnswerCall element into the application canvas area

accept a signal from the user input device to select a SetMedia element in the toolbox, wherein the SetMedia element has associated functionality for setting parameters in a media device;

accept a signal from the user input device to move a copy of the SetMedia element into the application canvas area;

accept a signal from the user input device to make a first connection from an output of the first AnswerCall element in the application canvas area to the SetMedia element in the application canvas area, wherein the first connection includes an arrow at the SetMedia element in the application canvas area;

accept a signal from the user input device to make a second connection from an output of the first AnswerCall element in the application canvas area to the second AnswerCall element in the application canvas area, wherein the second connection includes an arrow at the second AnswerCall element in the application canvas area;

receive a signal from the user input device to compile the application; and

generate executable statements that include script commands associated with the first and second AnswerCall elements and the SetMedia element to generate at least a portion of the functionality of the telephony application.

12. The apparatus of claim **11**, wherein the logic when executed by the computer processor is further operable to display a plurality of tabs in the application canvas area for the associated functionality for answering a call when the first or the second AnswerCall element is selected.

13. The apparatus of claim **12**, wherein the logic when executed by the computer processor is further operable to accept a signal from a user input device to select one of the plurality of tabs for display of the associated functionality related to the selected AnswerCall element.

14. The apparatus of claim **11**, wherein the logic when executed by the computer processor is further operable to accept a signal from the user input device to select a SendUserInput element, wherein the SendUserInput element has associated functionality for defining user inputs when answering a call.

15. The apparatus of claim **14**, wherein the logic when executed by the computer processor is further operable to accept a signal from the user input device to make a third connection from an output of the SetMedia element in the application canvas area to the SendUserInput element in the application canvas area, wherein the third connection includes an arrow at the SendUserInput element in the application canvas area.

16. The apparatus of claim **14**, wherein the logic when executed by the computer processor is further operable to accept a signal from the user input device to select an EndFunction element.

17. The apparatus of claim **16**, wherein the logic when executed by the computer processor is further operable to accept a signal from the user input device to make a fourth connection from an output of the SendUserInput element in the application canvas area to the EndFunction element in the application canvas area, wherein the fourth connection includes an arrow at the EndFunction element in the application canvas area.

18. A computer-readable storage medium for execution on a computer processor to create a telephony application using a graphical user interface, the storage medium comprising:

one or more instructions for displaying a visual designer having the graphical user interface, wherein the visual designer is displayed on a display screen using instructions executed by the computer processor, wherein the computer processor is coupled to a user input device, wherein the visual designer provides user interface controls for creating fin telephony application;

one or more instructions for displaying a toolbox area in a first area on the display screen, wherein the toolbox area includes elements;

one or more instructions for displaying an application canvas area in a second area on the display screen;

one or more instructions for displaying an overview window in a third area on the display screen, the overview window displaying a smaller current view of the application canvas area;

one or more instructions for accepting a signal from the user input device to select a first AnswerCall element in the toolbox, wherein the first AnswerCall element has associated functionality for answering a call;

one or more instructions for accepting a signal from the user input device to move a copy of the first AnswerCall element into the application canvas area;

one or more instructions for accepting a signal from the user input device to select a second AnswerCall element in the toolbox, wherein the second AnswerCall element has associated functionality for answering a call;

one or more instructions for accepting a signal from the user input device to move a copy of the second AnswerCall element into the application canvas area;

one or more instructions for accepting a signal from the user input device to select a SetMedia element in the toolbox, wherein the SetMedia element has associated functionality for setting parameters in a media device;

one or more instructions for accepting a signal from the user input device to move a copy of the SetMedia element into the application canvas area;

one or more instructions for accepting a signal from the user input device to make a first connection from an output of the first AnswerCall element in the application canvas area to the SetMedia element in the application canvas area, wherein the first connection includes an arrow at the SetMedia element in the application canvas area;

one or more instructions for accepting a signal from the user input device to make a second connection from an output of the first AnswerCall element in the application canvas area to the second AnswerCall element in the application canvas area, wherein the second connection includes an arrow at the second AnswerCall element in the application canvas area;

one or more instructions for receiving a signal from the user input device to compile the application; and

one or more instructions for generating executable statements that include script commands associated with the first and second AnswerCall elements and the SetMedia element to generate at least a portion of the functionality of the telephony application.

19. The computer-readable storage medium of claim **18**, further comprising one or more instructions for displaying a plurality of tabs in the application canvas area for the associated functionality for answering a call when the first or the second AnswerCall element is selected.

20. The computer-readable storage medium of claim **19**, further comprising one or more instructions for displaying event handler actions in a text box area in the application canvas area for the associated functionality for answering the call when the first or the second AnswerCall element is selected.

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